Scientific American

—FOUNDED 1845—

JANUARY
1948

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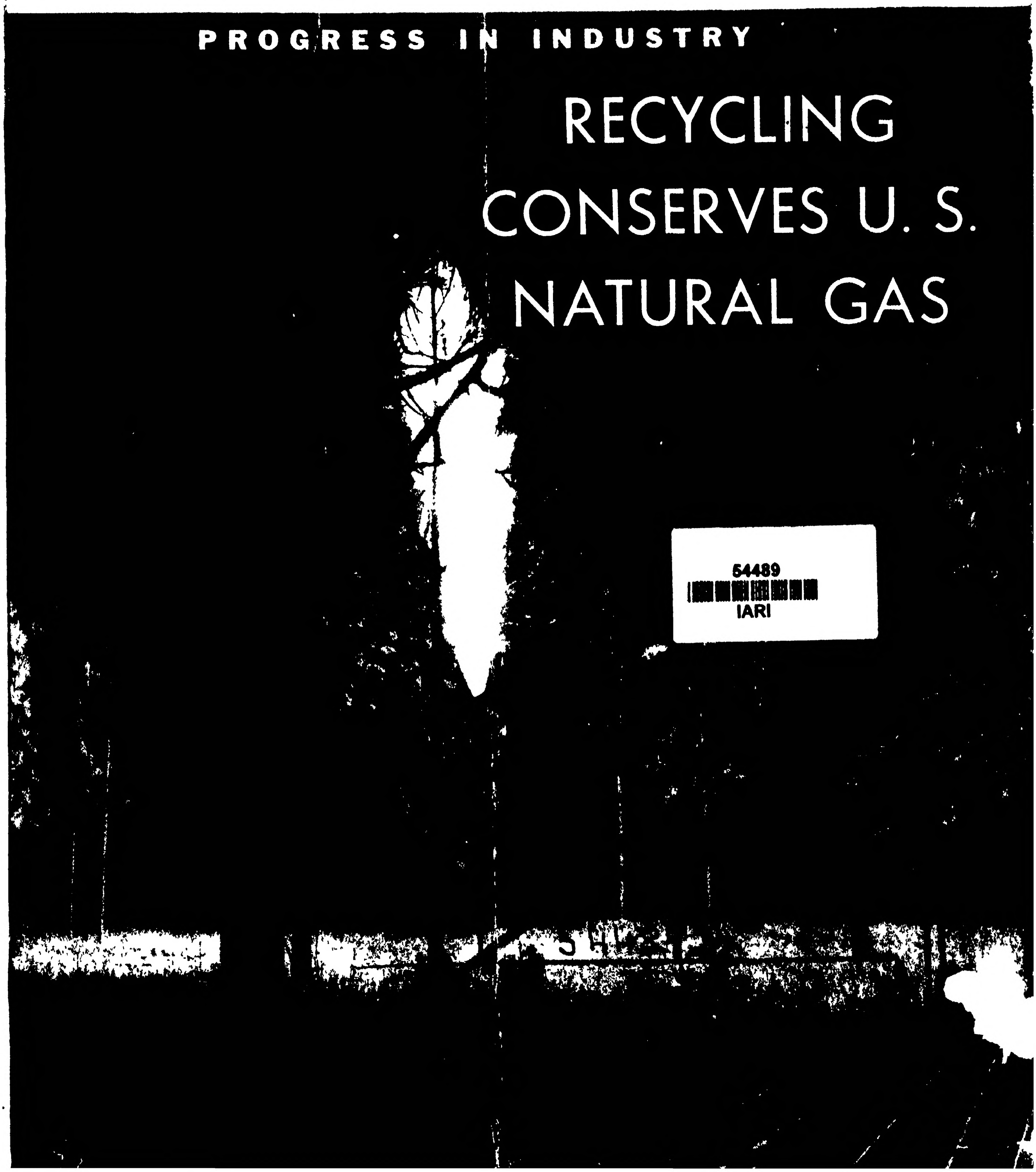
PROGRESS IN INDUSTRY

RECYCLING CONSERVES U. S. NATURAL GAS



ON THE COVER: Natural gas being flared off in the field. Definite steps are now being taken to curb such waste. For story, see page 16.

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50 Years Ago in . . .

(Condensed from Issues of January, 1898)

NOBEL'S WILL — "The will of the late Alfred Nobel, the Swedish chemist, and expert in high explosives, who died at San Remo, Italy, on December 9, 1896, has been proved. The personalty is valued at $2,170,465. About half the estate goes to relatives and the remainder is invested, the interest to be divided annually into five prizes of about $10,000 each. Prizes one, two, and three are to be awarded to the persons making the most important discoveries in physics, chemistry, physiology or medicine."

SUBMARINE — "Our accompanying illustration shows the construction and operation of a submarine wrecking boat which has been designed to enable divers' quarters and the air-compressing plant, tools, winches, etc., to be placed at the bottom of the ocean in close proximity to a wreck. The many advantages of such a device, if it can be successfully

operated, are obvious, and the details of the design as worked out by Mr. Simon Lake, of Baltimore, Md., are certainly full of interest."

VOLTAIRE AND ROUSSEAU — "A commission that was nominated by M. Rambaud, opened the tombs in the Pantheon at Paris, December 18, and settled the question of the whereabout of the ashes of Voltaire and Rousseau. Both skeletons were found. Voltaire's skull had fallen into two pieces, which when placed together gave a striking presentment of his features. The skull of Rousseau showed no trace of a bullet wound, thus disapproving the widely entertained belief that he committed suicide by shooting himself in the head."

BROOKLYN BRIDGE — "The permission which has been granted by the trustees of the New York and Brooklyn Suspension Bridge to the Brooklyn trolley companies to run their cars across the structure has aroused opposition on various grounds, the most serious of which is that it is not strong enough to carry safely the increased loads which will be put upon it."

AROUND THE WORLD — "In less than a quarter of a century, the feat of touring the world in eighty days has passed out of the realm of fiction into that of fact, but we find ourselves within a few years of the day when the ordinary This will be possible just as soon as the Trans-Siberian railroad is completed, or early in the twentieth century. The Russian minister of communication, M. Chilkov, has stated that when the great railroad is opened the tour of the world can be completed in thirty-three days."

EARLY FLIGHT — "The fact that so many gifted scientists and engineers are engaged on the problem of artificial flight affords, in itself, a strong presumption that sooner or later a successful motor-driven flying machine will be an accomplished fact. We publish in the current issue a remarkable paper by Octave Chanute, the distinguished engineer and scientist, which gives the results of his own exhaustive experiments of the last few years to determine the principles of flight. The elements to be determined are as follows: The supporting power and resistance of the air; the motor, its character and energy; the instrument for obtaining propulsion; the form and kind of the apparatus; the extent of the sustaining surfaces; the material and texture of the apparatus; the maintenance of equilibrium; the guidance in any desired direction; the starting up under all conditions; the alighting safely anywhere."

100 Years Ago in . . .

SCIENTIFIC AMERICAN

(Condensed from Issues of January, 1848)

SMITHSONIAN — "By accounts from Washington we learn that the Smithsonian Institute is in the course of erection, and that it is to be a large and elegant Gothic structure. We hope that the edifice will be an honor to America and a noble monument to the generous donor, who with prophetic eye looked down the stream of time and beheld Columbia as the centre of the civilized world."

BREECH LOADING — "A Swedish officer has invented a new kind of cannon, several pieces of which have been sent to Woolwich for trial. These guns are grooved like a rifle, and are not loaded at the mouth, but at the breech. The alleged advantages of these guns are that they are free from the danger of explosion, that the gunners are concealed while loading, and that the shot are thrown with greater accuracy of aim."

LIGHT FROM ELECTRICITY — "Mr. Staite, having decomposed water and produced light by it, through the agency of electricity, has been lecturing before the Philosophical Society of Sunderland, (Eng.) and has perfectly astonished the inhabitants of that place. The light which was of astonishing brilliance and beauty, was placed under an air-tight glass vase. When the gas was turned down it sufficiently lighted the spacious building, and bore the closest resemblance to the great orb of day of any light, it is said, ever exhibited."

ASTROGRAPHY — "Professor Nichol remarked in closing his lecture at Cambridge, Massachusetts, that if the sun could be made to assist in taking pictures of objects upon the earth, he could not see why a contrivance might not be fixed upon to daguerreotype his own picture. All that the astronomer would have to do would be to go to his study and use the microscope, and he could there examine all the different aspects of the sun."

RATTLESNAKE BITE — "A correspondent of the Philadelphia Inquirer states that tobacco applied to the wound made by a rattlesnake's bite, is an antidote to the deadly effects of its poison. Dr. Lee, of Hartford, Connecticut, states that he has treated a number of cases successfully at the South by application inwardly of alcoholic liquors."

AN ANNOUNCEMENT TO OUR READERS (II)

In the December issue this page carried an announcement of the forthcoming publication of a new Scientific American, under a new ownership and a new board of editors. The 103-year-old Scientific American is now to become a magazine of all the sciences, covering the physical, biological and social sciences as well as their more significant applications in medicine and engineering. The new Scientific American will be directed to the growing community of U. S. citizens who share a responsible interest in the advance and application of science.

The Scientific American has now entered the period of preparation which must precede the publication of any new magazine. This period will end with the appearance of the first issue of the new Scientific American in the spring. Until then, however, the Scientific American will continue regular publication without major change, reporting the practical applications of science in industry.

The December announcement to our readers also contained a brief description of the principles which will govern the editorial content of the new Scientific American. One fundamental principle is founded on the proposition that scientists, doctors and engineers today have an increasing concern that their work shall be more fully understood by their fellow citizens. It is accordingly expected that scientists, doctors and engineers will take an active part in the creation of the magazine's editorial content. The remainder of this page will be devoted to a closer examination of this assumption.

The Scientist and the Journalist

The editors of the new Scientific American believe that the men who are best qualified to write about science are scientists. They will therefore devote considerable effort to the solicitation of original writing from scientists. But since relatively few scientists have either the time or the inclination to write for an audience outside their own specialized fields, a large share of the writing which will appear in the new Scientific American must be undertaken by the editors, journalists who have had wide experience in the reporting of science. The editors recognize that the writing of science involves profound difficulties for both scientists and journalists. In the case of the scientist, the difficulties are largely those of clear communication at the non-technical level. For the journalist they are those of information and full understanding. The solution of the dilemma lies in the unique qualifications the scientist and journalist each bring to the task of science writing when they work together. This is what they will do in the new Scientific American.

The Role of the Scientist

The scientists whose work is reported in the new Scientific American will provide the substance of its articles. They will be the senior partners in their collaboration with the editors. They will not only furnish the facts, but also will share in the treatment of the facts. They will review the work of the editors for errors of omission as well as those of commission. They will, in short, take part in the development of each article from its conception to the time it goes to press.

The Role of the Journalist

The journalist's contribution to this collaboration is his command of the art of clear communication. The editors of the new Scientific American will write in plain English. They will use the vocabulary of the intelligent layman, which is the vocabulary of the scientist outside his own field. The journalist will also contribute the resources of modern graphic art to extend the power of words in expressing the ideas of science.

The End Product

The editors of the new Scientific American have often been asked: If your articles meet the scientist's standard of interest and accuracy, will they be understood by intelligent laymen? The answer states a fundamental conviction of the editors: There is no inherent mystery in the nature of scientific knowledge which prevents its communication to the interested, though uninformed, layman. Before the immense range of scientific knowledge all men, not excepting scientists, are laymen. In the new Scientific American, the scientific and the non-scientific layman will meet on the common ground of their interest in science.

Completely swathed in protective clothing a health physics inspector measures radiation intensity with a fish pole meter

Scientific American
JANUARY • 1948

RADIATION SAFETY: A NEW INDUSTRIAL PROBLEM

By Dr. Karl Z. Morgan
Director, Health Physics Department,
Clinton Laboratories,
Oak Ridge, Tennessee

Elaborate Safety Measures Have Been Developed By the Health Physics Departments of Atomic Energy Plants to Protect Both the Workers and the General Public from Dangerous Radiations. These Protective Measures, Proved Successful in Small Scale Operations, Will Aid Greatly in Solving the Staggering Radiation Safety Problems of the Large Scale Atomic Energy Plants

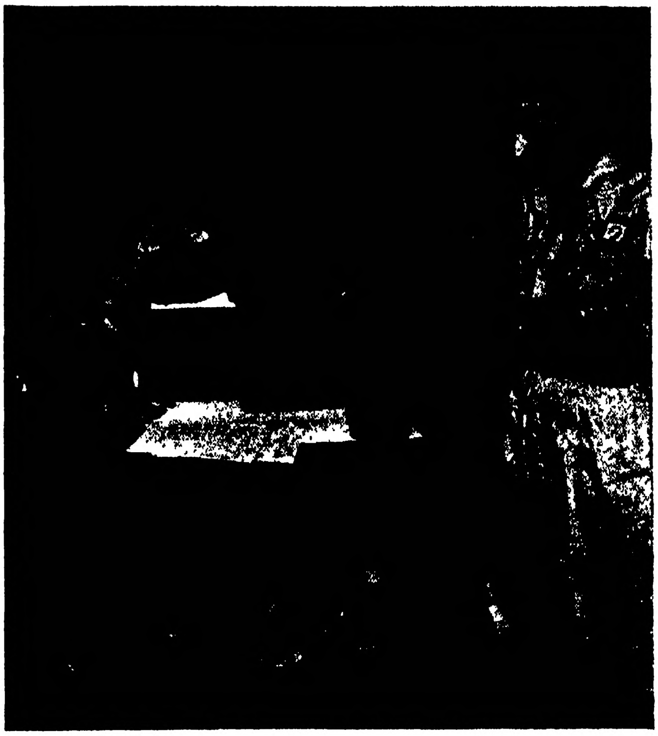
THE ATOMIC AGE began when Wilhelm Konrad von Roentgen discovered X-rays in 1895 and Antoine Henri Becquerel first observed the radioactivity of uranium in 1896. Almost from the beginning it was recognized that these developments could lead either to the unraveling of many problems on which man had labored for centuries, or, if unprecedented protective measures were not taken against these radiations, to suffering and death.

With the development of Einstein's theory, with the discovery of many particles of matter such as the electron, proton, neutron, positron and meson, and with the improvement in methods of accelerating these particles to high velocities, man began to realize the dream of the alchemist. He was able to change one element into another and could even convert mass to energy on a small scale.

It was only a few months after the discovery of X-rays that it was first found necessary to seek a cure for X-ray burns. Since then hundreds of persons have been injured and many have died as a result of the careless or improper use of this new form of energy. When the first atomic pile was set into operation on December 2, 1942, it was necessary to pause and consider whether it was wise to proceed with this important but dangerous development. It was estimated that if plans were carried out for the construction of the experimental pile at Oak Ridge and of the large production pile at Hanford, thousands of times as many curies* would be handled by the plutonium project workers as had been handled since the Curies discovered radium in 1898. The project directors reasoned that if radiation accidents were permitted to increase in proportion to the probable increase in radiation exposure, the sad experiences of the radium industry would be multiplied many thousand times.

HEALTH PHYSICS DEPARTMENTS — In an effort to find a solution to this problem, a department for the protection of the health of the plutonium project workers was established at the University of Chicago in the summer of 1942. From the start the principal duty of this department was understood to be "to make a study of radiation problems and to develop means for the protection of man from radiation ex-

*A quantity of radiation equal to that produced by one gram of radium

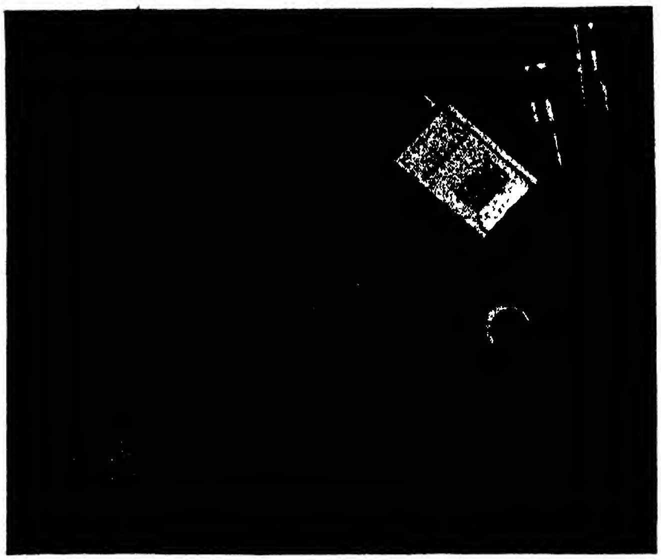


Vial of radioactive iodine is packed for shipment in a well shielded container. Worker in background checks the surface of another container for excessive radiation

posure." The leaders in this field have been physicists and physicians, but many chemists, engineers and men from other professions have also been trained to do the work.

The radiation protection programs of Health Physics Departments at the University of Chicago, Oak Ridge's Clinton Laboratories, and Hanford are essentially the same, except for those problems dependent upon the scale of operations. Basically, the programs call for the following:

1. The development of new instruments and techniques for protection from radiation.
2. The calculation of safe tolerance levels of radiation exposure, the development of efficient shielding methods and the solution of radiation scattering problems.
3. Personnel monitoring, by which all persons exposed to radiations are provided with meters so that a record can be kept of the radiation exposure they receive. Thus a suitable warning can be given immediately when tolerance levels are reached.
4. Surveys of buildings, by which the various working areas are w :hed constantly to insure that working condition· are safe.
5 Off-area sur eys of the air and water in the neighborhood of the plants to guarantee that the levels of contamination do not exceed appreciably the natural background levels of radiation that are always present.
6. Educational and consultation programs, by which everyone exposed to radiation in the laboratories and everyone using radioactive materials sent out from the plants is furnished with radiation protection information and learns how to follow all necessary protection measures.



Ion chambers in breast pocket and film meter on lapel are standard equipment. Small meters (note finger and wrist) may be worn on parts of the body especially subject to exposure

By standing on platform and placing his hands in the spaces provided the worker checks his hands and feet for possible contamination

In all of the plants, elaborate precautions are taken whenever radioactive isotopes must be handled. The isotopes themselves are moved with long tongs so that workers may remain as far as possible from the source of radiation. During periods of possible radiation exposure, a Health Physics Department supervisor maintains a constant watch on the radiation level with a hand instrument known affectionately as "Cutie Pie." At the same time a larger instrument, the Monitron, continuously measures the level of radiation, sounding an alarm if the eight-hour tolerance of radiation is reached When a temporary radiation shield is needed, lead bricks are used.

Isotopes to be shipped to hospitals or laboratories are packed in specially designed lead pots. After each sample has been sealed in the shipping container, the Health Physics Department supervisor takes careful measurements to make certain that no radioactive contamination has gotten on the outside of the container. The entire container is then carefully examined for radiation leaks with a portable Geiger counter. The level of radiation intensity is further checked with an electroscope to see that the radiation penetrating the container does not exceed 15 milliroentgens per hour. This leaves a considerable margin of safety, since the level suggested by the United States shipping regulations is 200 milliroentgens per hour.

PERSONNEL MONITORING — Each person entering a restricted area on the plutonium project picks up a film meter and two ion chambers from his assigned rack. Two ion chambers are carried to minimize accidental errors of instrumentation. These three meters are carried by the worker during his normal duties and at the end of the shift are returned to the same rack. The ion chambers are examined immediately by Health Physics Department technicians. If *both* pocket chambers indicate a significant

fraction of a day's tolerance exposure, the film meter is read and an investigation is made the following morning to make certain that no one has been exposed to excessive radiation.

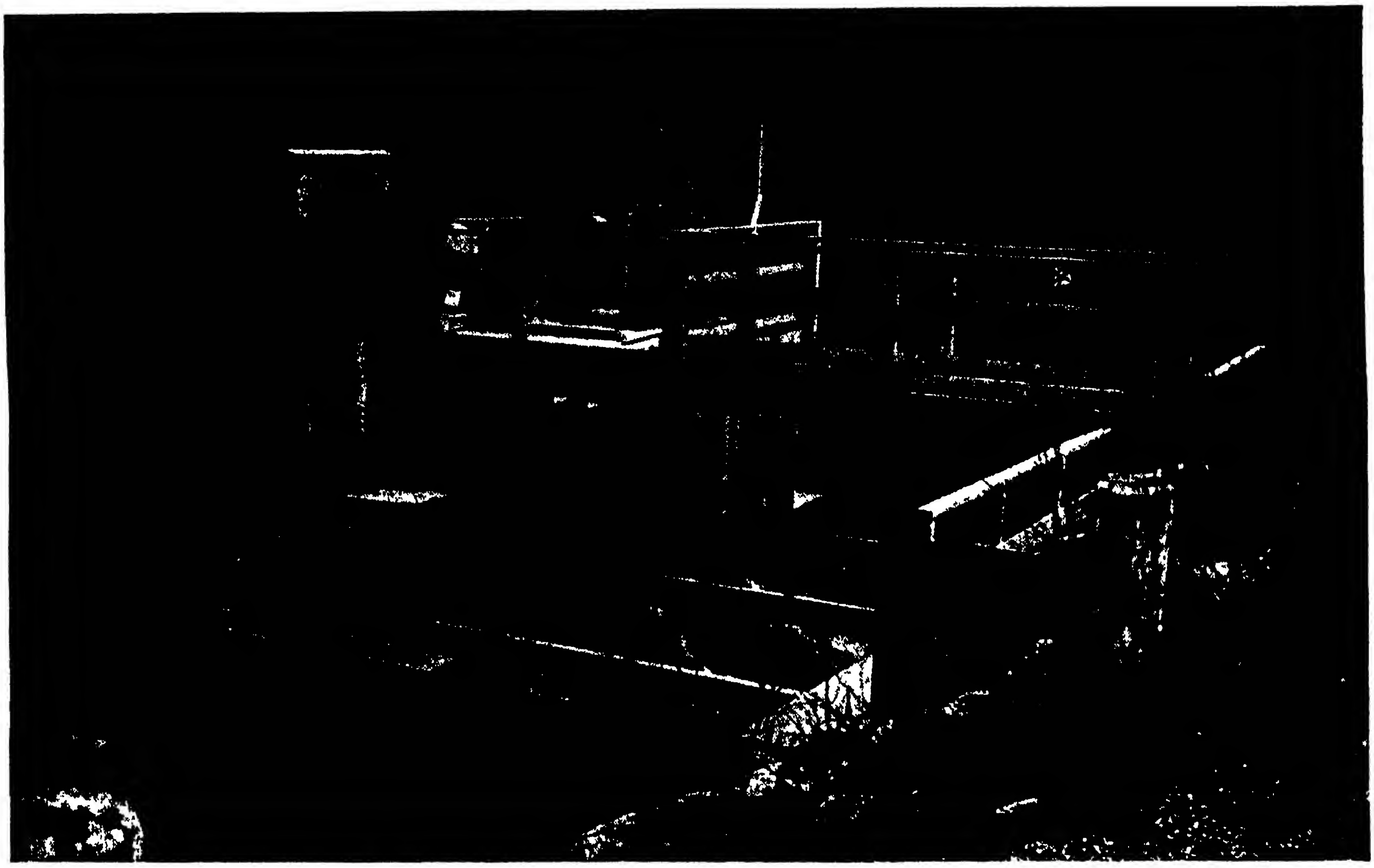
The film meter contains ordinary dental X-ray film, part of which is covered by a cadmium shield. Measured by photometer, the blackening of the film under the cadmium shield is proportional to the gamma ray exposure. The blackening of the unshielded portion of the film is proportional to the exposure to beta particles or soft X-rays which are less penetrating. A special neutron film meter is worn by those who work with neutrons, and the proton recoil tracks are counted on this film after it is developed. The counting is done with the aid of a dark field microscope, and the density of the proton tracks is proportional to the neutron exposure.

Perhaps one of the most unusual operations for health protection at an atomic energy plant is the decontamination laundry. All persons working in restricted areas wear protective clothing which must be washed regularly. The decontamination laundry uses conventional detergents to remove dirt, and a citric acid solution to remove radioactive isotopes. All garments are carefully checked with a Geiger counter for beta and gamma activity before they leave the laundry. Where necessary, other garments are checked for contamination by isotopes which emit alpha particles.

RADIOACTIVE WASTE DISPOSAL — All contaminated solid waste material from atomic energy plants is buried in guarded areas. Most of the liquid radioactive waste is stored in large tanks, although a small fraction is discharged into holding ponds and streams. Conditions in these ponds and streams are very closely controlled. For example, at White Oak Lake, a holding pond located about two miles from Clinton Laboratories, screens prevent fish from entering the restricted area. Instruments housed in a small building on the dam monitor the water continuously. Unusually high radiation standards are set by the Health Physics Department for water in the vicinity of Clinton Laboratories. It must be safe for continuous use either as drinking water or for swimming. Added to all this, the water leaving the holding pond is diluted by the Cinch River a hundred fold.

Instruments to measure radioactivity in the air are scattered around all buildings of the plutonium projects and the area surrounding them. In these, air is drawn through filter paper which surrounds a Geiger counter at the center of a large cylindrical

Operator (right) removes a radioactive isotope from the pile. Health physics inspector (left) monitors the job with a fish pole meter



The water contaminated by radioactive materials is held in ponds where instruments (in shed) monitor it continuously

lead shield. This filter removes some of the suspended radioactive contaminants from the air. The output of each Geiger counter operates a pen which keeps a written record of the air activity by marking a moving tape. The air activity, according to Health Physics Department requirements, must not exceed the order of normal background levels. Air always contains uranium, thorium, actinium, and their radioactive decay products This, together with cosmic rays, composes the natural radiation background to which man is always subjected.

All these radiation safety precautions are expensive and require a great deal of effort and concern to everyone working on these plutonium projects. They have, however, paid great dividends. No one on any of these projects, as far as is known today, has been injured by radiation exposure. In fact, no one is believed to have averaged a radiation exposure that exceeds 10 per cent of the established tolerance level. This is a remarkable statement in view of the fact that these people are working with *millions* of curies of radioactive material. There is considerable evidence that as long as present standards are maintained, and as long as the Health Physics Departments continue to function properly, the plutonium projects will remain among the safest industrial operations in this country.

It should be pointed out that it has been no easy problem for the health physics programs to keep pace with the rapid expansion in the use of atomic energy and its products. Often new instruments had to be used in mass quantities when they were little better than experimental models. Today the reverse is true. Many instruments are available on the projects, and are badly needed elsewhere, but are not available due to the delays of declassification.

SHORTAGE OF MEN — There has always been a shortage of men with the proper interests, education and experience in health physics. Only time and great efforts can relieve this shortage. Health physics is demonstrating its necessity in a nation at peace, but should an atomic war come, thousands of men will be needed who have the proper training in this new profession. Some leaders in our country, having observed this problem, have taken preliminary steps to train an army of men to operate Geiger-Mueller counters and a few other health physics instruments. However, this leads our people only into a false sense of security. A man with the wrong instruments and with improper knowledge of how to use them or interpret the results will only complicate an emergency. A man with a scalpel, a stethoscope and a few weeks of training would not be a useful substitute for a doctor for the same reasons.

The great need is for more leading health physicists who have an understanding of the problems of decontamination; who know how to determine if the radiation levels are safe in a city water supply; who can state when certain areas should be evacuated after a city has become the target of an atomic bomb. Perhaps the best solution is to increase the educational efforts on the plutonium projects, and for more competent scientists to begin this training.

ONE THIRD OF WOOD

Editor's note: The following article will appear as part of Dr. Glesinger's book *The Coming Age of Wood,* to be published in the spring by Simon and Schuster, New York.

By Dr. Egon Glesinger
Director, Division of Forest Products, United Nations Food and Agriculture Organization

Lignin, Companion of Cellulose as a Main Chemical Constituent of Wood, Resists Both Analysis and Utilization. New Laboratory Work, However, May Yet Make It a Valuable Raw Material. The First of Two Articles

Much of America's favorite ice-cream flavor comes not from the essence of a tropical bean, but from the lignin of Wisconsin spruce and fir, converted into synthetic vanilla. Given this diverting piece of information, the consumer has every right to ask: What is lignin? With that, he joins the company of some of the world's most distinguished scientists, who have been plagued for years by this same question. They know that lignin constitutes from 20 to 30 per cent of all wood, but have yet to determine its exact chemical structure and properties. Most wood chemists agree that lignin is a particularly rich substance and expect to find in it a major source for plastics and even synthetic gasoline. Yet, today, lignin is still nearly 100 per cent waste, and a nuisance besides.

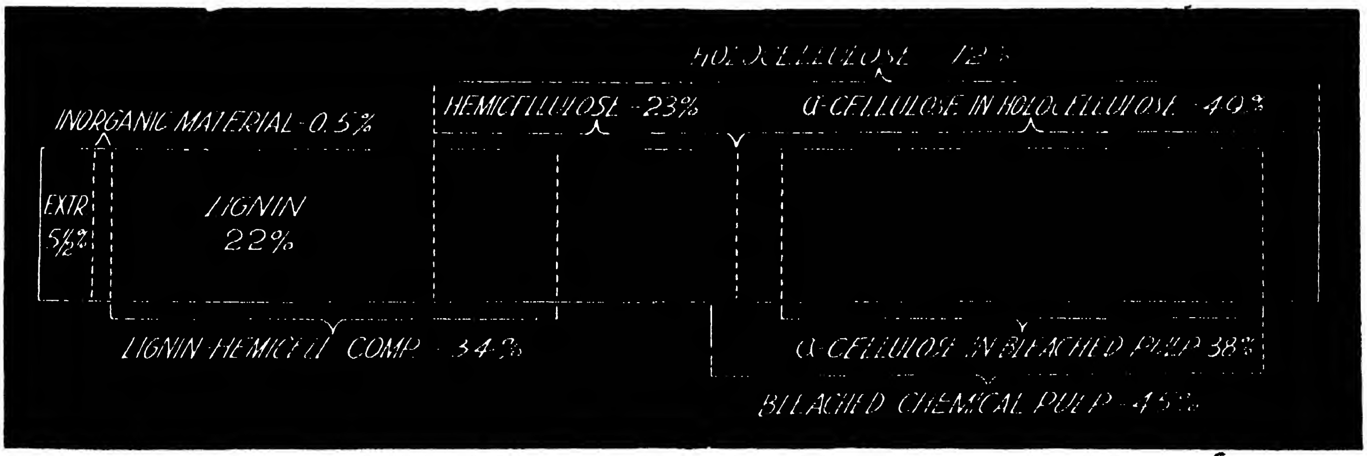
Derived from *lignum,* the Latin word for wood, "lignin" means literally "wood substance." This designation might be challenged on the ground that there is about twice as much cellulose in wood as lignin The name is justified, however, because it is lignin that differentiates trees from other cellulose plants, which have very little lignin in their structural make-up.

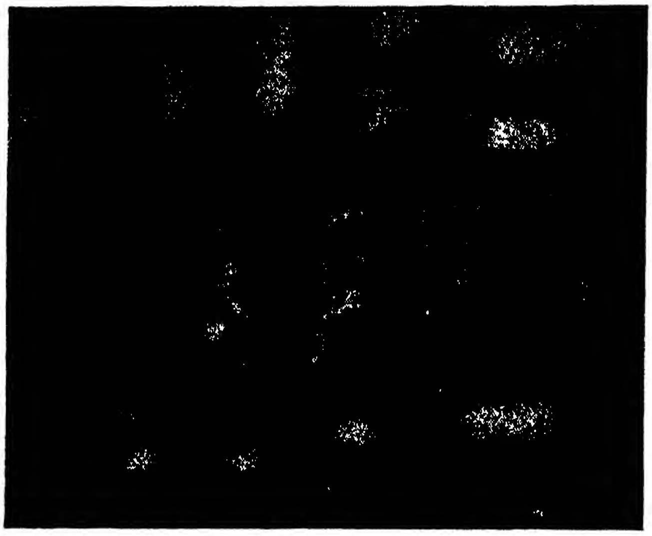
Without lignin, trees could never grow several hundred feet tall, stand up against storms, and support heavy loads of snow. Binding together parallel bundles of cellulose fibers, lignin acts as nature's plastic and gives wood its stiffness, impact strength and resilience. Its action might be compared to that of the cement that surrounds and binds the iron rods in reinforced concrete. Nature itself thus suggests that we take lignin and use it as a binder for making cellulose plastics. Unfortunately, this is more easily said than done. For the lignin commercially available today refuses to duplicate its performance in nature.

FOSSIL LIGNIN — Lignin is believed to have another, more fascinating assignment in nature. When trees die, they are attacked by various microbes. These microbes attack and destroy only the cellulose fibers of wood, leaving the lignin. If this was as true in prehistoric times as it is today, then coal is not just wood, as is generally believed, but lignin fossilized by the action of heat, pressure and time. Chemical analysis tends to confirm this theory. Lignin's carbon content of 70 per cent is closer to that of coal than of whole wood. Again, nature suggests that we look into lignin for the riches we have extracted from coal, starting with aspirin and running to xylol. But, again, the genie of lignin is confined to the test tube.

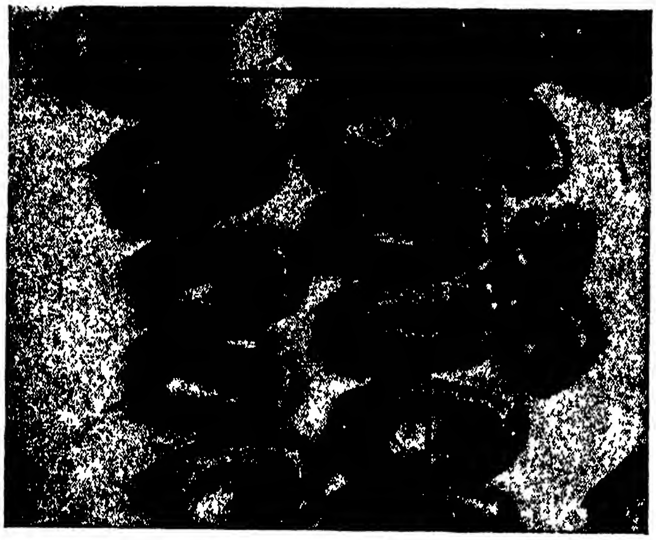
Our trouble comes not only from our ignorance about lignin, but also from the methods by which we extract it from wood. Unlike cellulose, which grows free and pure in the cotton boll, there is no such thing as free lignin in nature. Lignin is found only in close bond with cellulose. Chemists have never sepa-

The chemical constituents of wood. Total cellulose, here defined as holocellulose, is broken down into low-grade hemicellulose and high-grade alpha cellulose. Lignin occurs naturally in chemical combination with hemicellulose to make up 34 per cent of wood. When it is separated from hemicellulose it makes up 22 per cent

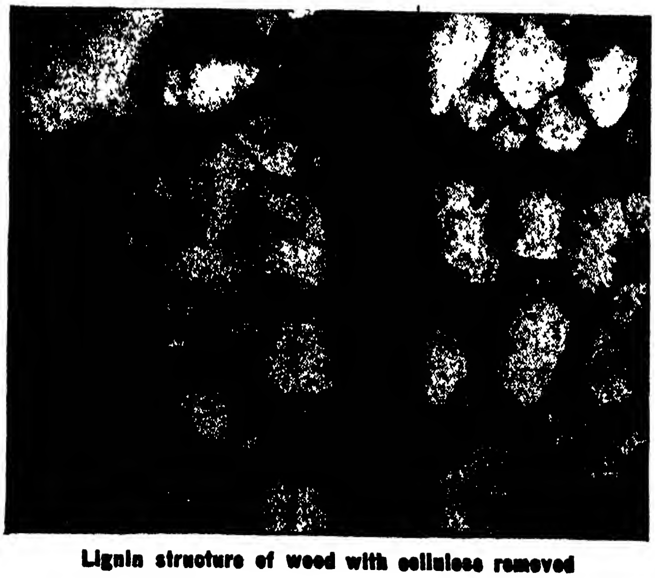




Magnified cross section of wood



Cellulose fibers of wood with lignin removed



Lignin structure of wood with cellulose removed

rated it from cellulose with its natural qualities intact. Just what these qualities are, they are not sure either, although they have made some careful deductions. It is pretty clear that natural lignin is colorless, possibly transparent. Its action in holding wood together indicates that it is stable, unaffected by moisture and normal temperatures, and elastic. Unhappily, lignin is very much degraded by the industrial pulping and wood-sugar processes.

The divorce of lignin from cellulose was first accomplished on an industrial scale by a Swede, C. E. Ekman, who started the manufacture of chemical wood pulp in 1870. The wood pulp yielded by his sulfite process was, of course, the cellulose content of wood. The lignin, which was extracted at the rate of twelve hundred pounds per ton of wood pulp, was of interest only as a constituent of the waste liquors. This interest, in turn, arose from the public outcry that the infant chemical pulp industry find something better to do with its waste liquors than pollute the streams.

Waste-liquor research has since made progress. In the wood sugars, which constitute one third of the solids in waste liquors, it has found a valuable enough product to justify the expense in plant and fuel required to boil off the nine parts of water in which each part of waste-liquor solids is dissolved. The lignin that emerges from this process, as the remaining two thirds of the waste-liquor solids, however, is a discouraging, sticky brown powder. It shows little or no sign of chemical life or reactivity. Repeated failures to bring it to life have forced many wood industrialists to conclude that the best thing the scientists can do with lignin is find a cheap way to get rid of it. Research continues, however, on more constructive lines, and today scientists are cheered by indications that it is getting warm.

"BURN IT" — Meanwhile, the most practical solution the research directors of pulp companies are able to submit to the front office is to let lignin supply the fuel required for the pulping process. There is much to recommend this arrangement. It takes about half a ton of anthracite coal or its equivalent to manufacture a ton of chemical pulp. With a fuel value of 10,500 B.T.U. per pound, lignin is almost 50 per cent more efficient than whole wood and has about 75 per cent of the efficiency of hard coal. Nothing could be more logical than to use the nonfibrous and coal-like portion of wood as the source of the heat, power and steam required to extract wood's cellulose and convert it into fiber products.

The economies achieved by using lignin fuel account in large part for the recent spectacular advance of the sulfate pulping process. During the past fifteen years, it has doubled its share in the world output of chemical pulp and has dislodged the sulfite—or acid—pulping process from first place in North America. Using an alkaline instead of an acid, the sulfate process yields a waste liquor from which the lignin is more readily recovered. By burning lignin in their boilers, sulfate mills achieved an immediate reduction in coal consumption from 1000 to 300 pounds per ton of cellulose. Recent improvements have made the sulfate process completely self-sustaining in its energy requirements. The nascent wood-sugar industry has begun to make similar use of its lignin, although with regret, because its lignin shows definitely better

promise than does that of the pulp processes.

Sulfite factories, on the other hand, continue to buy practically all of their fuel and to discharge their lignin into the streams, even when they process and concentrate the waste liquors for the recovery of sugar. They hold that it would cost far more to clean their pipe lines and evaporators of the deposits formed by the lignin associations peculiar to the sulfite process than to buy all the coal they need and forget about lignin. The sulfite industry, accordingly, throws away some six million tons of lignin each year.

The annual heat requirements of the world's chemical pulp industries are the equivalent of eight million tons of anthracite. This fuel bill could be eliminated entirely by proper use of waste liquors. If this were done, lignin would yield every day a respectable total energy output equal to twelve times the total generating capacity of Grand Coulee and Bonneville dams. Use as fuel, however, confers very little value on lignin. With a coal price of $6 per ton, lignin fuel is worth from $2 to $4, compared to the earnings of $30 to $100 of its senior partner, cellulose. The best that can be said for lignin as fuel is that it is better to burn it than to dump it into rivers.

Compared to these two equally poor alternatives, the possibilities of lignin when chemically converted read like a tale by H. G. Wells. Lignin as fuel is not worth even a fifth of a cent a pound. The cheapest bulk chemicals, on the other hand, bring in ten cents a pound; fifty cents is not unusual, and in the field of pharmaceutics and cosmetics—the Hollywood of chemistry—prices are quoted in dollars.

IT TAKES MORE THAN FLAVOR — Synthetic vanillin is a perfect example of the high-grade products and prices lignin might yield. Obtained by treating waste sulfite liquors with an alkali, vanillin sells for $3 a pound. Unfortunately, one day's operation by United States sulfite pulp mills produces enough waste-liquor lignin to cover the nation's vanilla consumption for a full year. And since the remaining 2000 million human beings consume substantially less vanillin in toto than America's 140 million sweet-tooths, vanillin can never be more than a drop from the waste-liquor bucket.

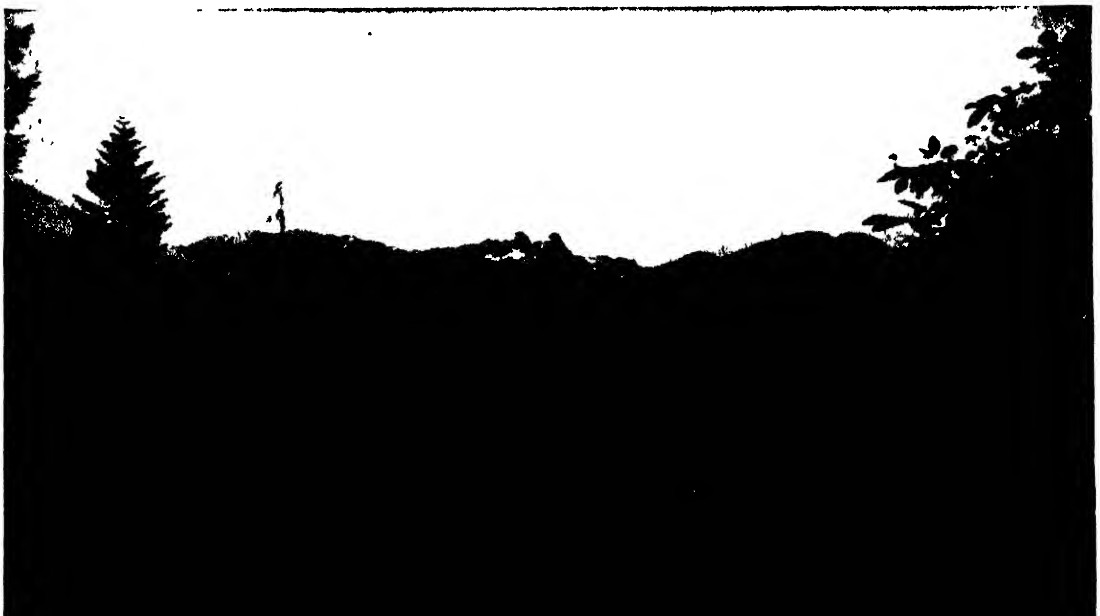
Though it still has a long way to go, lignin's commercial career does not begin and end with vanillin. Wartime scarcity of other materials in Germany and Sweden, for example, brought about the use of considerable amounts of waste liquors in the manufacture of soap. The product did not make the grade as bath or toilet soap, but it was completely satisfactory for laundry use and helped these nations to reduce their consumption of fats and oils in soap to one third.

Excellent qualities as a tanning agent have found lignin another market in the leather industry. Penetrating the cosmetics industry, lignin is an ingredient in some hand lotions and scalp tonics. It serves also in several well-known bactericides and fire extinguishers.

Advantage is taken of lignin's natural plastic properties by using it as a rubber extender, a road binder and as an admixture to phenolic resins. A concoction of lignin and concrete is the basis for a number of new building materials and panels.

As a constituent of natural humus, the biggest single deficiency in agricultural soils, lignin shows great promise as a fertilizer. Enriched with elemental phosphorous and nitrogen, lignin promotes the formation of topsoil and thus might be used to extend farming to poor soils in heavily forested countries.

These applications of lignin either involve trifling quantities or, where they call for heavy tonnages, confer no higher value on lignin than its use as fuel. Moreover, none of them expresses lignin's great potential value as a chemical raw material. This remains the objective of the research now moving forward in almost all forest-product laboratories.



A forest in Vancouver. When its trees are used for pulp, nearly a third of the wealth of such forest land is wasted by the loss of lignin.

WHERE DOES POWDER METALLURGY STAND TODAY?

The Present State of a New Technology Introduced To Industry in the Thirties Is Reviewed

By H. R. Clauser
Associate Editor, MATERIALS & METHODS

ALTHOUGH the powder metallurgy process has been available to industry on a reasonably large scale for almost ten years now, industry is still somewhat confused as to just where this method of producing metal parts fits into the production picture. Even the metal powder producers and powder parts fabricators themselves are somewhat uncertain of their present and future status.

Probably the main reason for all this uncertainty is that powder metallurgy is still a relatively young process. Not young in the sense that it was just recently invented, because metal powders have been used for a number of centuries. But young in an engineering and commercial way. It has only been the last ten or fifteen years that powder metallurgy has been developed to the point where it can be used efficiently for more than just a few items. During the war powder metallurgy expanded and got a landslide of publicity. It was labeled a new and revolutionary process that had an extremely bright future. But that early publicity is now gone; the process must now support itself on its real merits and somehow find its place in the industrial production picture.

Some of the more outspoken and enthusiastic supporters of powder metallurgy have been inclined to talk of it as a cure-all, while detractors of the process have sometimes said that it is good for nothing. Of course neither of these extreme opinions is correct. Powder metallurgy is an engineering method of producing certain metal parts, and like all metalworking processes it has a definite set of capabilities and limitations which defines its range of usefulness in industry. So let's see what the process is, what its good and bad points are, what it can be used for and what some of the latest developments are.

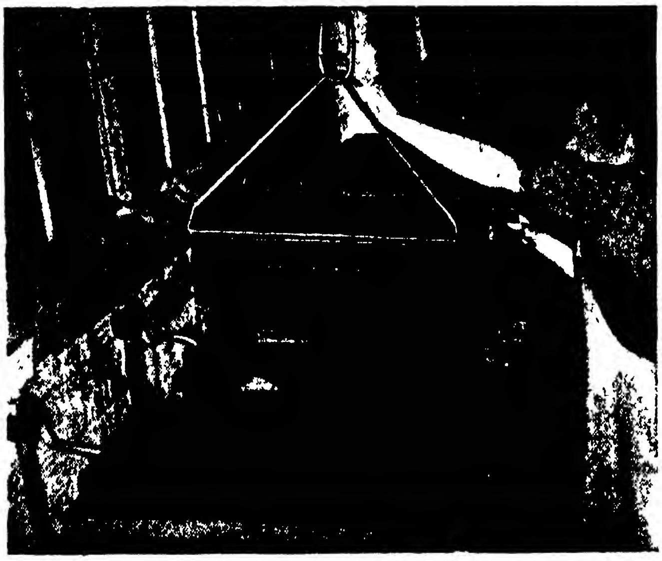
Clutch parts formed by the powder metallurgy technique

THE PROCESS — The manufacture of a part by powder metallurgy methods involves three major steps. First, the metal powder or powders are pressed in a mold or die to form a weak, "green" briquette that has approximately the final shape. The pressure of the press varies from 5 to over 100 tons per square inch. This press size is an important factor in limiting the size of parts possible.

After pressing, the briquette is sintered to bring it up to service strength by heating it to some temperature below the melting point of the powders. Sintering causes the solid particles of powder to bond together by atomic forces. The heating is usually done in an atmosphere or vacuum furnace.

Finally the sintered part is re-sized or coined to final exact dimensions. This is another pressing operation in which the part is formed in a die of suitable size by pressure. Where special properties are required, such as in the case of "oil-less" bearings, the part is impregnated with oil before the final re-sizing operation.

Powder metallurgy is primarily a small parts production method. High production rates can be attained by using automatic machinery. Outputs ranging up to 1800 pieces per hour are not uncommon



Porous bearings made from powdered metal be- [redacted]
ing removed from the oil-impregnation bath

and in some cases it has been as high as several thousand per hour. Rather close dimensional tolerances can be held, even under high production conditions. On large work tolerances of about ±0.002 inch can be held, while on small parts they may be as low as ±0.001 inch. With special jobs tolerances of ±0.0005 inch are possible. The method involves fewer total operations than many other forming methods and can sometimes be more economical because of such things as low labor costs, high-speed production, elimination of machining and finishing costs and very little raw material waste. Also tooling costs are relatively low and set-up for production is fast.

On the other hand, the cost of metal powders is high and their availability is often a problem; the cost of dies for the pressing operations is also high. The size and form of products is limited. They must be relatively simple in shape, and their size is restricted by available presses. Parts around four square inches in section are generally the maximum. However bearings as large as 18 inches in diameter have been made. The strength, impact and elongation properties are not as good as those obtained in cast and wrought materials. And finally there are a number of design limitations that must be observed. Such things are sharp corners, large and abrupt changes in thickness and uneven cross sections must be avoided.

APPLICATIONS OF THE PROCESS — The applications or uses of powder metallurgy fall into two main groups: (1) It is used for parts which are difficult or impossible to make by any other method; and (2) It is used for making conventional parts which can be made by other metal forming methods such as machining, casting, automatic screw machine and forging.

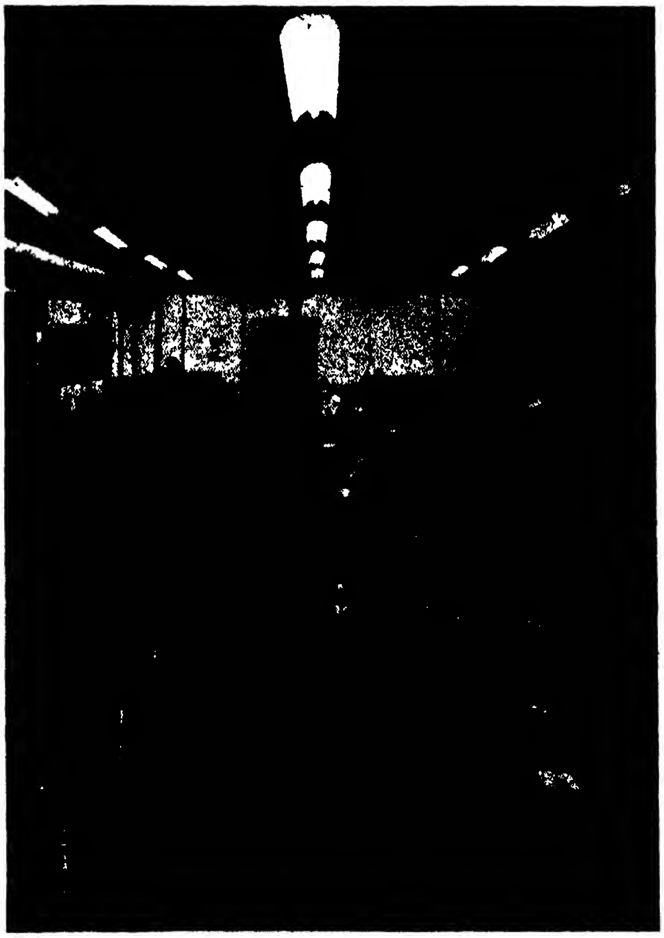
In the past, and still at present, the principal applications of powder metallurgy are in the first group. For example, refractory metals like tungsten and molybdenum, because of their high melting points cannot be produced efficiently by other means. By powder metallurgy methods, solid bars of these metals are obtained. They can then be further shaped to final forms by swaging or rolling or drawn into wire for a variety of uses.

Combinations of metal powders to produce products retaining the characteristics of each of the component metals are also possible by powder metallurgy. The best known example of this is cemented carbides. Here a small amount of cobalt is used with tungsten carbide powder to give an extremely hard, relatively strong product. Cemented carbides are used for cutting tools and dies, and for wear and corrosion resistant parts.

Porous bearings are probably the best known products made of metal powders. They are one of a number of products that take advantage of the uniform and conttrolled porosity present in metal powder parts. The bearings are impregnated with oil, usually sufficient to last the lifetime of the part. Metallic filters of powdered metals are another application that make use of this controlled porosity.

Magnetic cores used in all telephones and radios are a powder metallurgy product. They are formed with metal powders, each particle of which is coated with an insulating material. Cores of this nature could be made by no other process. For the electrical industry many types of current collector brushes and electrical contacts are made by powder metallurgy. Welding electrodes and small magnets can also be

Powder metal weighing and blending room is carefully air conditioned to avoid contaminating the hydroscopic materials



made of metal powders. And metallic friction materials composed of non-metallic ingredients in a metallic matrix are being used in clutch plates and brake bands to improve wear life under severe operating conditions.

During the war powder metallurgy was used in a number of instances to produce parts ordinarily made by such methods as casting or automatic machining techniques. In some cases the results were so promising that powder metallurgy replaced the conventional method and many predicted that it would take over many of the jobs now being done by other methods. However, in general there has been some disappointment in the lack of progress being made in this new direction of large volume production of small parts such as gears, cams, bushings and the like. In spite of the attractive advantages such as high rates of production, low metal loss and elimination of machining costs, indications are that present and future progress into this competitive field will depend largely on a number of other factors. One of the most important of these is the raw material problem. It is principally a problem of getting high-quality metal powders at a reasonably low cost.

PRODUCTION OF METAL POWDERS — At present most of the metal powders used on a large scale are made by either atomization, electrodeposition or by chemical methods. In the atomization method the solid metal is melted and then shot through a small nozzle orifice. A stream of compressed air, steam or an inert gas striking the molten metal as it comes out of the nozzle breaks it up into fine particles. The particles are collected by ordinary dust collectors and are then ready for use. Atomization is used for making low-melting point metal powders such as lead, zinc, copper, aluminum and their alloys. The powders obtained are irregular in shape, have good density and are usually quite uniform in size.

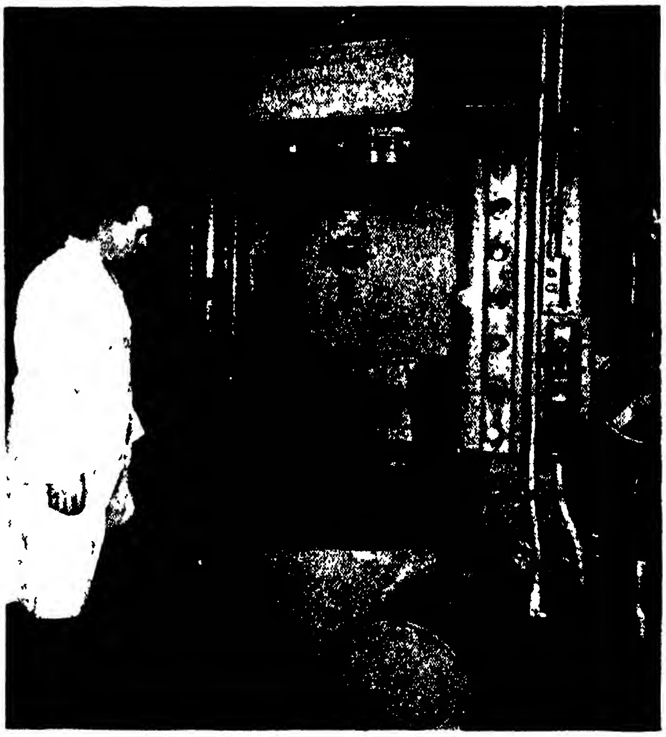
The electrodeposition method is the same as that used in electroplating of metals, except that the conditions are reversed. In electroplating a hard, tenacious layer of metal is formed on the part serving as the electrode; in producing metal powder, however, a loose, brittle deposit is formed on the anode. This powdery deposit can be further ground or crushed to smaller particles. The particles are usually dendritic in shape and since they are of low specific gravity usually require heat treatment before molding. The common powdered metals made by this process include tin, silver, copper, zinc and iron.

The chemical methods in which metal oxides or salts are reduced by gases, account for the largest amount of powders used by the powder metallurgy industry today. The oxide of the metal is most generally used. It is a very flexible process and a wide range of characteristics and properties are possible. Among the metal powders made in this way are iron, copper, nickel, cobalt, molybdenum and tungsten.

The carbonyl process should also be mentioned, because it gives some of the purest and finest metal powders. The process depends upon the decomposition of metal carbonyls which are produced by passing carbon monoxide over the spongy metal at proper temperatures and pressures. When the carbonyl decomposes, the metal powder is precipitated. Iron and nickel powders with superior properties are made in this way.

Practically all metals can be made in powder form by one of the processes described above or by one of a number of less common methods. However, the methods are still too costly and it will be necessary

A carefully measured quantity of tungsten carbide powder is poured into the die to make a carbide machining tool



Filled with tungsten carbide powder, the die is placed in the press where the "green" briquette will be formed

to develop ways and means of producing powders cheaply either by these established methods or by new processes.

LOW-COST HIGH-QUALITY POWDER NEEDED — Before powder metallurgy can seriously compete with other metal forming methods on a large scale, cheap high-quality iron powder must be made available.

In the past much of our iron powder has been imported from Sweden and also some from Germany. Many fabricators are still importing their powder from Sweden. In fact, until recently the Swedish process had been the only commercial method of making iron powder at relatively low cost.

During the past few years domestic production capacity of iron powders has been increased by the development and use of several new production methods. Reports are that our domestic capacity is now between 10,000 and 12,000 tons per year. But at present this capacity is not being fully used.

The price of iron powders ranges all the way from seven and eight cents for Swedish low-grade sponge iron to over $1.00 a pound for the higher grades. Although domestic producers are now almost meeting the price of low-grade imported iron powders, the problem of bringing down the cost of the high-grade iron powders still remains. There is much talk about how this might be done. The two things most often mentioned are standardizing on a fewer number of different grades, and increasing the use of iron powwers and thereby increase the volume of production

ALLOY POWDERS — The low properties—strength, elongation and impact—of metal powders as compared to those obtainable in cast and wrought metals is another factor that is hindering the rapid growth of powder metallurgy. Recent developments in alloy powders may do much towards eliminating this disadvantage.

The carbide briquette coming from the hydraulic press must now be sintered to bring it up too full service strength

In early methods of making alloy powder parts, the separate constituents of the alloy desired were combined by solid diffusion during the actual production of the part. The latest method is to use "pre-alloyed" powders. These are powders consisting of two or more elements made in alloy form before being fabricated into parts. Copper alloys, such as brass, have been pre-alloyed commercially for quite a number of years by means of the atomization method.

By using various newly developed processes a large number of alloy powders can now be produced by disintegration of the alloy material when it is in its molten form.

These alloy powders reduce the sintering time over that necessary for diffusion sintering. Also they usually have improved mechanical properties. The full affect that the development of these pre-alloyed powders will have on the powder metallurgy industry is still not known. However, it is generally believed that they will expand the use of the process.

Another possible means of improving the properties of powder metallurgy parts is by use of hot-pressing methods. Experiments have indicated that when metal powders are pressed in a heated instead of cold condition high density parts having comparatively high strengths are possible. Also, the pressing pressures required are much lower than those required for cold-pressing. The manufacture of large metal powder parts has been limited because very large, expensive pressing equipment is required. If hot-pressing lives up to its early promises, parts much larger than those now possible will come within range of the powder metallurgy process.

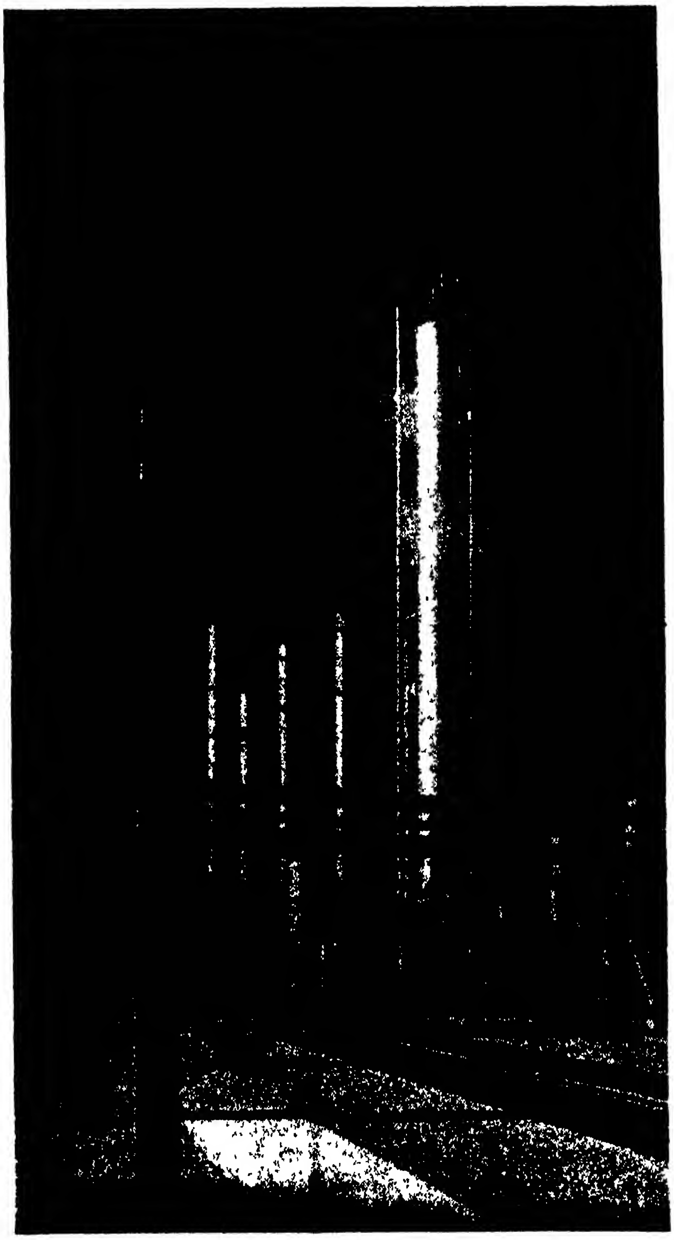
Hot-pressing should also aid the expansion of alloy powder parts. Many pre-alloyed powder materials require very high pressures when cold-pressed to attain their optimum properties. However, hot-pressing in many cases results in satisfactory properties at reduced pressures. Before hot-pressing can be used extensively on a commercial basis a number of problems—such as preventing oxidation during heating and eliminating excessive die wear—must be solved.

And finally, the future of powder metallurgy depends, to a considerable degree, upon the attitude of industry. In the past, many manufacturers have depended largely upon independent powder parts fabricators, because they have felt that the process is too complicated or that the cost of equipment is too high. Thus, metal powder parts have usually cost far more than they would have, had they been made right in the manufacturer's own plant. To take full advantage of powder metallurgy, industry must treat it as a metal parts production method just as it does die casting, forging or stamping. Actually, the cost of powder metallurgy equipment is no higher than that for most other production forming methods, nor is the process more complicated. So in time, when more of industry gets better acquainted with powder metallurgy's capabilities, and puts it in the production line like automatic screw machines and other metal forming machinery, we can expect to see powder metallurgy become a full-fledged production method.

RECYCLING CONSERVES U. S. NATURAL GAS

Valuable Hydrocarbon Fractions Formerly Wasted Are Pumped Back into the Ground

By Neil Uptegrove



In this cluster of fractionators the desired light cuts are separated from the gas condensate

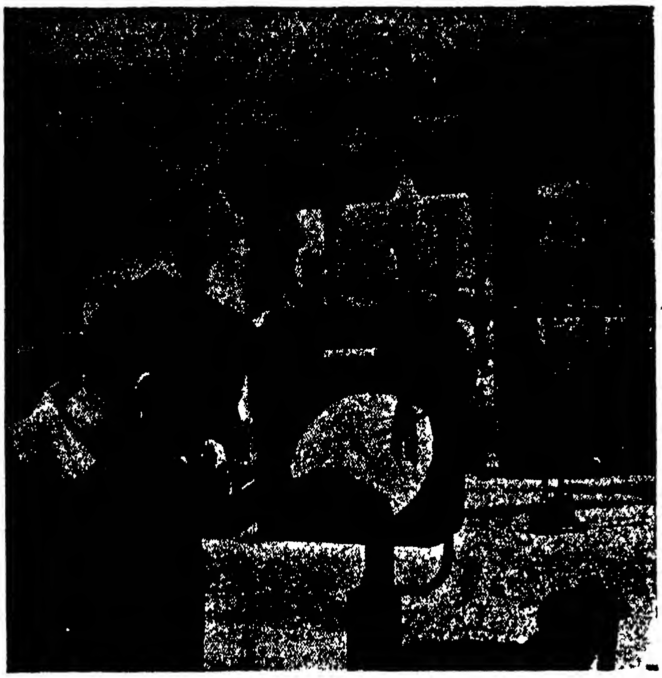
NATURAL GAS, the principal by-product of the petroleum industry, has generally been considered the worthless nuisance of the oilfields. Small quantities of natural gas have been used as fuel in oil-producing regions, but there have been few other markets of commercial significance for it. Most natural gas has simply been burned as it came out of the ground. This has not only wasted precious hydrocarbon fractions, but has also exhausted oilfields by reducing the underground pressure necessary to keep petroleum flowing to the wells.

In recent years the petroleum industry has become increasingly conscious of the fact that lost natural gas is lost wealth. Natural gas fractions, moreover, have become an essential adjunct to petroleum in the production of high-octane gasoline. The latest development has been that natural gas alone can be synthesized into gasoline by the Fischer-Tropsch process. These new uses require improved methods of producing and conserving natural gas. One such method which merits close attention is known as recycling.

Recycling, in brief, is a process whereby natural gas is tapped from high-pressure wells, the desired fractions (at present butane, propane and pentane) removed and the remaining gas pumped back into the ground. This final step 1) keeps the underground pressure, and therefore the productivity, of the field high and 2) conserves the remaining gas, still a rich store of hydrocarbons for the future.

In fields where gas alone is produced, recycling accomplishes another important end. This aspect of the process depends upon an unusual property of certain gases discovered by Kuenen in 1892. Kuenen found that whereas most gases condense into liquids when they are compressed, natural gas condenses when its pressure is decreased. He called this phenomenon "retrograde condensation." The traditional practice of the oilfields, in which natural gas escapes freely from the wells, causes many gas fractions to condense underground as the pressure falls. And because their high surface tension cleaves them to grains of sand, there they remain.

If the underground pressure is kept high enough to prevent condensation, however, these otherwise lost hydrocarbons can be removed in their gaseous state. This, the principal objective of recycling, makes possible the recovery of more than 70 per cent of the



This gage records the pressure of the residue gas as it is forced back into the ground

total reserve in a natural gas field. Since previous practice recovered no fractions that had condensed underground, recycling becomes a powerful agent for increased production as well as for conservation.

TWO SETS OF WELLS — Recycling requires two complete sets of gas wells. Production wells remove wet gas (i.e., gas containing all fractions) from gas-bearing strata. Injection wells pump the stripped gas back. The success of recyling depends largely on the proper placement of both. This requires a painstakingly accurate estimate of the size and shape of a gas field's underground reservoir. The most successful method of obtaining such an estimate to date has been through the use of the oil pool analyzer, a model of the field built from data supplied by geologists. When the model is filled with a conducting solution, the path of electric current through the solution is similar to the flow of gas through underground strata. This method has done much to make sure that injection wells are placed to spread the stripped gas uniformly, forcing the maximum quantity of wet gas into the production wells. Without such estimates, injection wells might be so badly placed that the stripped gas will travel in narrow channels and leave much wet gas behind.

Since an effective recycling operation must take in an entire gas field, it frequently requires close coöperation among companies who own various parts of the field. In fact, if a recycling operation is not run as a unit, it will fail as a unit. In sinking production and injection wells, property lines must be forgotten.

Such coöperation among companies on a recycling project can be far more difficult than it would appear. The legal problems encountered when several companies with various interests try to "unitize" a gas field can be enormous. Before any unity of effort can be obtained such questions as which company is to be the principal operator, how engineering decisions are to be made and how royalties are to be divided must be answered to the satisfaction of everyone concerned. In past years the difficulties encountered in the course of settling such problems have been the principal obstacle to starting a recycling program at all. But as the need for recycling has become more apparent, petroleum companies have participated in a trend toward a great community of effort.

An important stimulus for this trend has been the fact that the oil-producing states have begun to realize the value of recycling Led by Louisiana, several states have already passed legislation requiring that retrograde condensate fields be operated by recycling Other legislation has also prohibited the indiscriminate waste of natural gas.

The principle of recycling was first applied on a large scale in Texas in 1938. At first the wet gas from production wells was processed simply by retrograde condensation, i.e., the condensate was collected when wet gas from the wells was allowed to expand in closed chambers. Later a second type of separating plant came into use in which the wet gas was cooled to increase the efficiency of condensation. A third method, and now the most common, employs high-pressure absorption to extract condensate. This latter method yields more condensate than the others and has the additional advantage of requiring less horsepower for the compressors which force the stripped gas into injection wells.

RECYCLING AT ERATH — An outstanding example of a coöperative recycling project is the Erath Recycling Operation in Vermillion Parish of south central Louisiana. The first wells in this field were

Gas condensate is brought up from the reservoir by this pumping unit

drilled by the Texas Company in 1940, revealing that there was no significant accumulation of petroleum below 8000 feet. There was, however, a large quantity of natural gas and condensates from it. It was then decided to unitize the entire Erath field, build a plant to separate condensates from the gas and recycle the stripped gas.

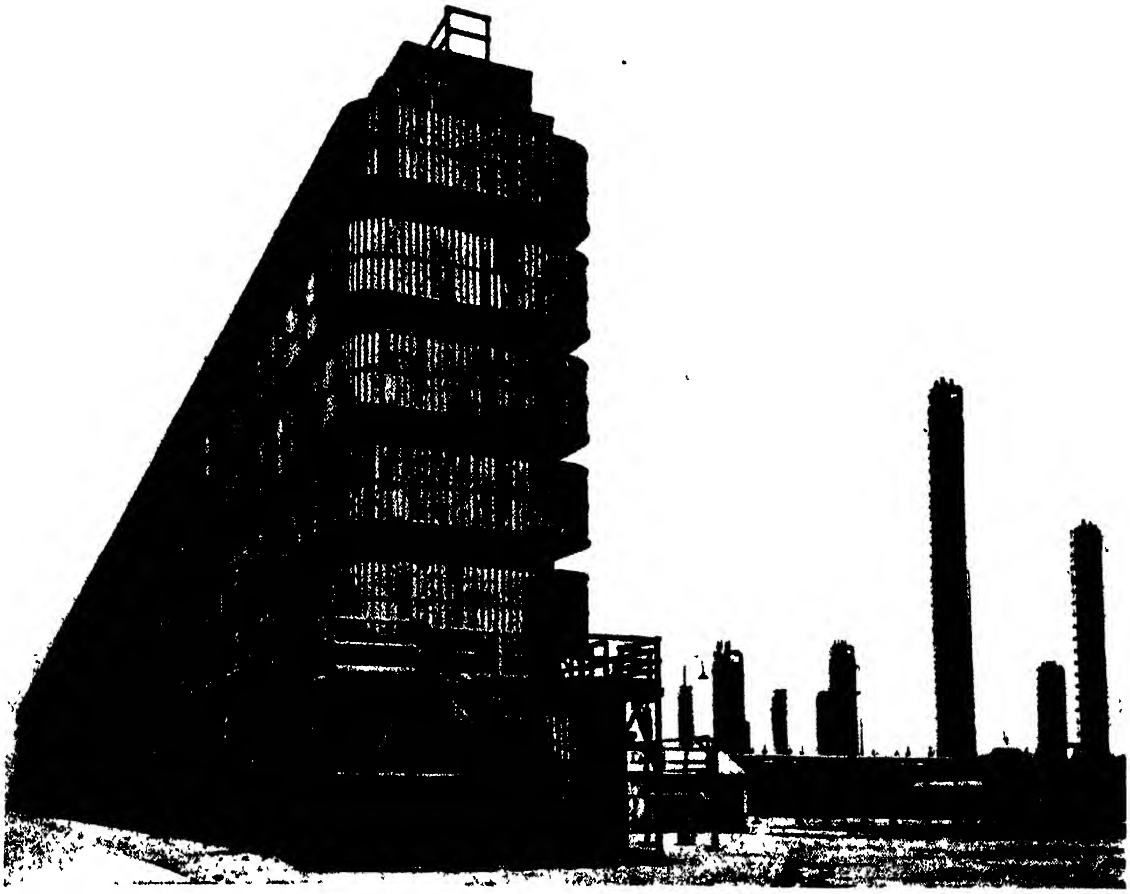
The Texas Company then proposed a plan for the coördinated development of the field in which the interest of each owner or leaseholder would be based on the relative value of hydrocarbons beneath each tract. The agreement was approved by 44 owners, some 400 leaseholders and royalty owners and by the Louisiana Department of Conservation.

Up to this point 11 wells had been drilled at Erath. After the field had been unitized, the total was brought up to 31 production wells and 12 injection wells. These wells made possible a production of 220,000,000 cubic feet of wet gas per day. The output of the plant which processed the gas for its desired fractions was approximately 16,000 barrels a day. After 11,000,000 cubic feet had been diverted as fuel to operate the Erath plant, some 197,000,000 cubic feet remained daily to be pumped back into the field through the injection wells.

GAS BEARING STRATA — There are 19 strata at Erath which bear gas and condensate, ranging in depth from 8100 to 11,970 feet. Pressures in the strata run from 3939 to 6245 pounds per square inch. The temperatures vary between 180 and 219 degrees F. When the gas is tapped from the production wells, it is under a pressure of 2500 pounds per square inch and at a temperature of 130 degrees. Its temperature lowered to 100 degrees in cooling towers, it proceeds to reducing regulators where the pressure is decreased to 1850 pounds per square inch. This drop in pressure lowers the temperature of the gas still more to 90 degrees. The wet gas then passes through separators which remove its cargo of condensate. Finally the condensate is fractionated by conventional methods of distillation.

When the gas leaves the separators, considerable care is taken to prevent fractions which condense under moderate pressure from going to the compressors. Suction scrubbers and high-pressure absorbers remove those fractions which have passed the separators. In the compressors, the pressure of the gas is raised again to 4600 pounds per square inch in one stage and is piped to the injection wells. Sixteen compressors of 800 horsepower each compress the stripped gas at Erath.

The recycling plant at Erath is the largest of its kind to be built to date. Its 16,000-barrel daily output of light hydrocarbon fractions, although it is only an insignificant part of the total production in Louisiana alone, is more than twice as large as the amount which could be produced by any other method. In these days of shrinking U. S. petroleum reserves, recycling offers real hope that the petroleum industry can increase the production of existing natural gas fields and open new fields which are closed to other methods of exploitation.



An atmospheric water cooling tower. In this tower vast quantities of water are chilled for use in the refining of the separated fractions

THE PILOT PLANT'S VALUE TO INDUSTRY

Editor's note: An enlarged version of the following article will appear in Mr. Killeffer's book *Methods of Industrial Research,* to be published in January by the Reinhold Publishing Corporation, New York.

By D. H. Killeffer
Chemical Engineer

If Properly Equipped, Staffed and Operated, The Pilot Plant Can Point the Way to Bring A New Industrial Process Safely Across the Gap of Uncertainty Existing Between the Laboratory Stage and Full-Scale Production

INDUSTRY generally can profit by adopting the chemical industry's pilot plant to guide its progress. Faced with serious difficulties in translating theoretical possibilities and laboratory experiments into going manufacture, the chemical industry invented the semi-works or pilot plant to "make your mistakes on a small scale so that your profits can be on a large one," as Baekeland put it. Or in the words of Kettering, the pilot plant is "a bridge across the shirt-losing gap" between laboratory experiment and plant production. The chemical industry had to develop something of the kind for its own survival since only in the most remote case can chemical processes be economically enlarged from test tube to tank directly without serious trouble Chemical reactions differ inherently from mechanical operations that can be multiplied simply by installing more machines of the same kind. Two machines make twice as many cigarettes as one, but to attempt to jump from a bare chemical idea or experiment directly to full-scale production is to court almost certain failure from the mis-function of little things (and others not so little). The cost of interruptions, spoiled goods and wasted time thus entailed can readily smother an otherwise promising development.

To avoid these casualties which have plagued it whenever progress is rapid and development general, the chemical industry has devised and adopted the technique of the pilot plant, capable of small-scale operation under close control, as a means of exploring new territory. This valuable tool, now well developed, could be profitably adopted by other branches of industry to carry out their explorations and to promote their progress.

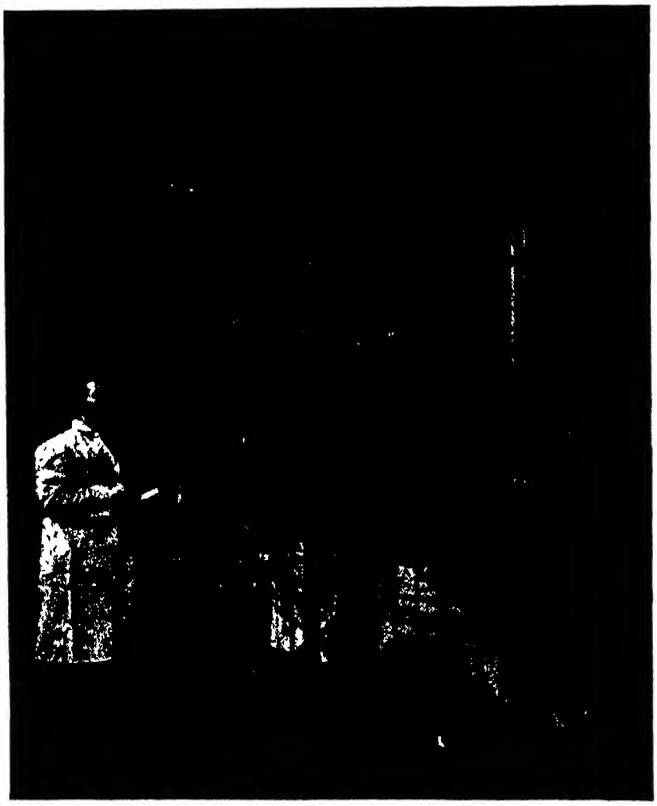
COMMON MEETING GROUND — In a very real sense the pilot plant is the halfway house of the chemical industry, for all the different phases of the industry meet here. Here the research chemist puts his reactions to their first test of production, but on a scale that avoids bankruptcy if they fail and undue danger if they run wild. Here the plant operating department, looking for improvements, can subject processes to the closest scrutiny and they can vary operating conditions without interrupting regular production. By operating processes in the pilot plant on a scale large enough to give meaning to the measurements taken from them, the engineering department can determine most, if not all, of the facts required to arrive at an efficient design for the full-scale production plant. Pilot plant operation can readily supply sufficient quantities of a new product, or a new modification of an old one, for distribution by the sales department to prospective users. This can yield a dependable estimate of market possibilities, covering quality, quantity and price of the product. All of these data, assembled and correlated, give management a penetrating analysis of the situation on which to base its decisions.

The pilot plant can, when properly used, safeguard the judgments of all concerned in the success of any enterprise. At the same time it provides a reasonable and practical meeting ground, more logical than the usual conference room, for settling differences between departments and for forming policies for the future. Here every aspect of each problem can be studied with great care and here the interchange of ideas and points of view between the several groups constituting the company's staff can take place on the common ground of determined facts.

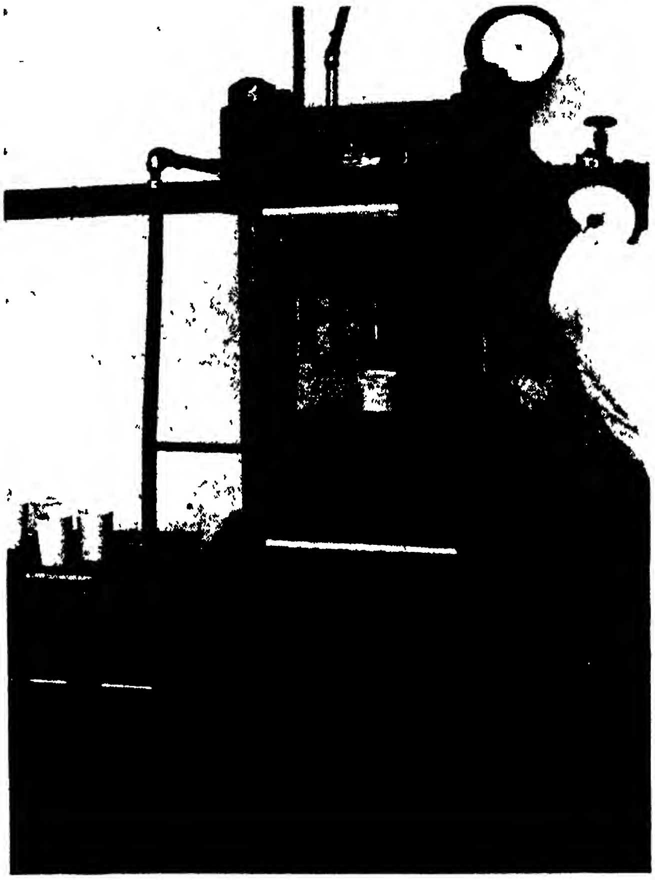
An instrument so potent for the good of an organization must of necessity be handled with skill and understanding if all its possibilities are to be realized. The pilot plant can yield abundantly if it is (1) amply equipped, (2) staffed by capable persons and (3) well understood by all departments of the company. A genius might possibly be able to produce results from a pilot plant whose equipment is drawn entirely from the junk pile of the maintenance department's final discards. But a genius could get along without a pilot plant at all! Since pilot plants

must be run by average to excellent research workers to give day to day good performance and not by geniuses to perform miracles, both equipment and personnel of the pilot plant must be adequate.

PILOT PLANT SET-UP — Necessarily the details of the pilot plant are determined by the general nature of its problems. The pilot plants of a glass works, a petroleum refinery, a textile mill and a dyestuff plant are totally different from each other except in their basic elements. For instance, each would need space enough to set up miniature duplicates of the principal units of equipment of the parent plant and room beyond that to allow these units to be moved about into various combinations. Furthermore, each unit as set up for work must be so situated that every part of it can be reached for measurements, alteration, cleaning, repair and any other purpose that the operator may be able to imagine. The working space of the pilot plant must be heated and ventilated adequately for its purposes and must be provided with all the services of the plant itself: water, sewer, steam, electricity, fuel gas, vacuum, air pressure and any others available. Every reasonable and some unreasonable safety devices must be at hand. The equipment of the pilot plant must include as a minimum an adequate set of mechanical tools for setting up and dismantling any or all of its equipment, and every type of measuring (and preferably automatically recording) device and instrument that may reasonably bear on its problems. Finally some provision must be made for the assembly and recording of data, at least a desk in a separate room where records can be kept and calculations made.



This laboratory-scale molecular still will have to undergo many modifications in the pilot plant stage before it can be applied successfully to full-scale production



Synthetic resins are molded into drinking tumblers in the press of this plastics pilot plant

Beyond these basic items, the pilot plant ordinarily duplicates the operating plant in miniature. Size is the most obvious difference, but in addition to that, the essential flexibility of the pilot plant requires a generous use of tees, unions, and flanged connections on each unit and plenty of thermometer wells and other connections for gages and meters of various kinds. Equipment should be mounted on dollys or casters to be easily moved about as needed. Large, heavy items—hydraulic presses, jacketed pressure vessels, furnaces and other cumbersome major pieces —can be permanently mounted on solid foundations, depending for flexibility on bringing up lighter items to be connected into the various systems required. Mechanical industries can profitably set aside a single production line for pilot purposes or build one especially.

PERSONNEL REQUIREMENTS — The personnel of the pilot plant staff is even more important than its physical equipment. The prime necessity is to provide a skeleton staff of one or more persons as may be required to be permanently attached to the pilot plant. This staff must be experienced in as many aspects of the company's business as possible

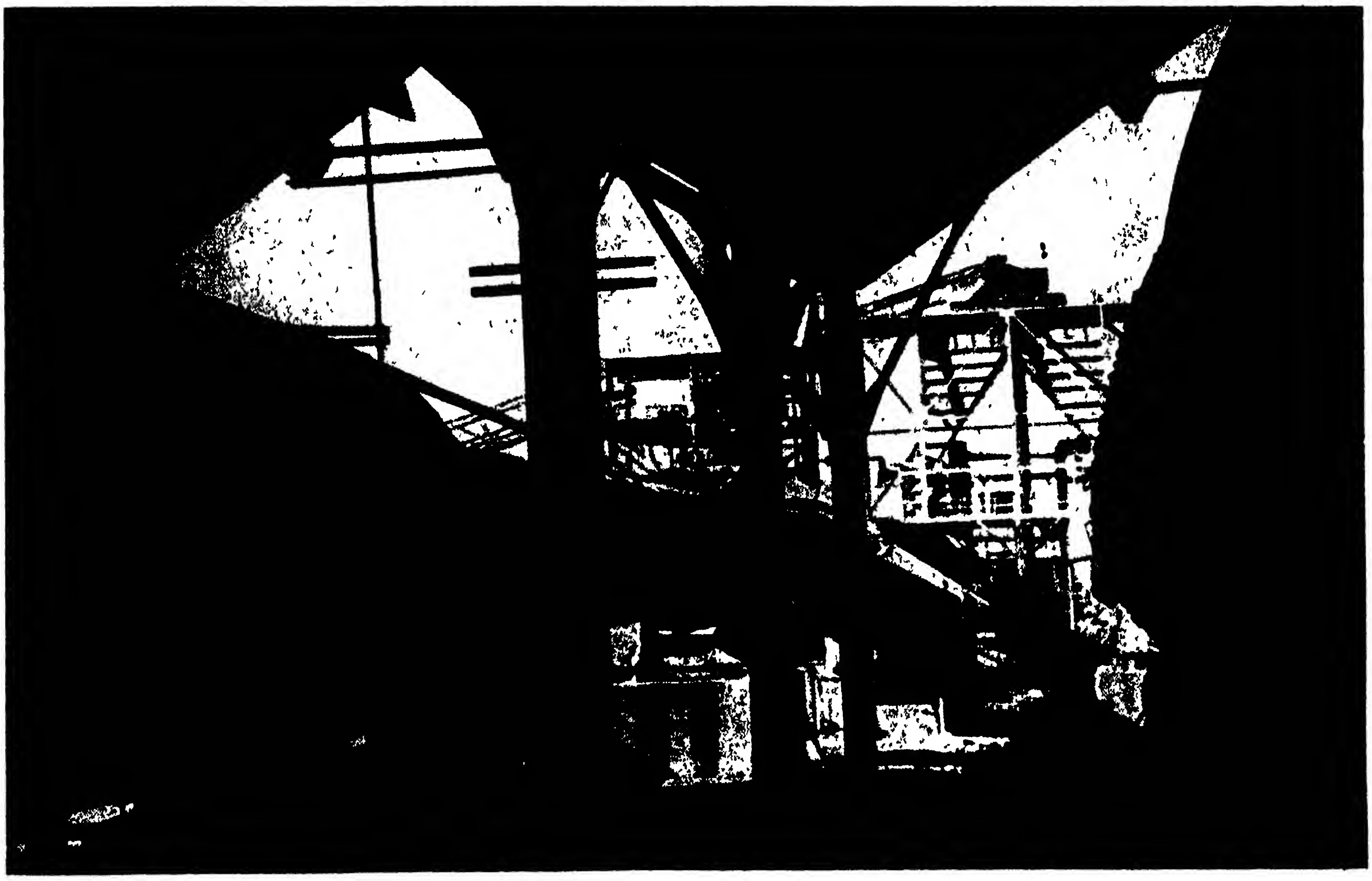
and certainly the director of the work must be thoroughly familiar with the points of view of research, production, sales and management. His inclination to go off the deep end in a research sense must be tempered by his desire in an operating sense to produce results as fast as needed; his salesman's optimism must be mixed with a generous share of management's conservatism. This individual must be so independent of each of these several divisions that none of them dominates him and that his thinking is not incompatible with any of them. Obviously such a person is impossible to find; but at least he is the one that should be sought, and the compromise person that is finally selected should be given a position as far as possible independent of each of the groups that will be his best customers—the company's department heads.

Having installed a minimum permanent staff in the well-equipped pilot plant, the next question is: How shall it function to best advantage? Necessarily someone from each of the other departments of the company interested in a particular problem must be available to solve it himself or with the assistance of others. When the pilot plant research approaches a point where some department other than its originator should be interested or should prepare to take over, then an appropriate person from that department should be available on loan. It is a mistake for any man whose primary interest is in some other department of the company to become permanently attached to the pilot staff. It is equally wrong not to send men from other departments into the pilot plant at reasonable intervals because each man can contribute to its effectiveness and each can learn something from it. M. C. Whitaker once emphasized the difference in men about the plant thus: "A man who is essentially a plant man is liable to be a nuisance in a research laboratory; and on the other hand, a man with research inclinations is a hazard to any production process." Yet these two types of men can safely and effectively meet in the pilot plant. Here the research-minded man can experiment to his heart's content without interfering with the regular progress of raw material into the main production line, and of finished goods out of it to customers. The production man for his part can watch in operation equipment more substantial than the glassware of the laboratory; he can also see a certain orderly progress of affairs that can be influenced and adjusted with a wrench and a screw driver instead of a glass blower's lamp and a piece of rubber tubing.

SALESMEN FAMILIARIZED — Here, too, the salesman can acquire some acquaintance with, and respect for, the processes and equipment that give him a product to sell. He can even operate the process himself without fear of drawing down the management's Jovian lightnings should something fail to go just right. This familiarity with his own product and a nodding acquaintance with the problems of others in supplying it have never yet been known to mar a salesman's effectiveness.

Finally the pilot plant provides an effective initi-

In the design of large installations such as this alkali works the pilot plant becomes an economic necessity



ation for any person entering a company with the expectation of assuming some responsibility for its affairs at once or later. The pilot plant's very nature makes this function simple and easy as well as time-saving and effective. Visitors are always problems in an operating plant and neophytes who are not definitely training to become operators must be classed as visitors whatever may be their histories and expectations. The operating force can seldom shut down an operation just to show a visitor how it works and certainly a shut-down cannot be timed to suit the visitor's whims. On the other hand, a trainee in the pilot plant can be given, under careful supervision, useful work to do in connection with its operation, and so earn his salt while learning.

No research and no development can be considered complete until it has survived the test of at least pilot plant operation. Here the research man continues to foster and cherish his offspring, but here he must transfer it by degrees to other's care. The stay of a process in the pilot plant may be considered to correspond to the period of adolescence in children. In infancy, the research man has complete control in every respect, but in the pilot plant his infant must be put through a process of growing up, of passing from the secure dependence of the research laboratory to the hazardous maturity of operation. It undergoes tremendous enlargement, but at the same time the new process is acquiring a purpose only dimly imagined in the laboratory.

Normal routine would require that the research man (or one chosen from the group if several have participated in the investigation) leave the laboratory and take his brain-child into the pilot plant. Here appropriate steps put the new process into operation. The staff of the pilot plant participates with the researcher in this, and as the work develops, representatives of the engineering department are called in to help things along. At a later stage a designated person from the sales department and another from the operating department may be called in to contribute to the development. Naturally, the sales department has no particular interest in the development of a totally internal process which will not affect the products for sale. Nor will the production department show serious interest in a totally new product until the sales department reports some actual or potential interest in it from the company's customers. Thus the burden of proof continues to rest at the point of origin, the research department, until some probable value of the development has been demonstrated. All of this consumes considerable time, but it also makes important opportunities to study the new process, to determine

A full-scale organic synthesis. To vary the arrangement of such equipment after it had been set into operation would be virtually impossible

its operating characteristics and to make enough of the product to develop some interest in it from potential customers and others than its parents in the research laboratory. The bugs in the process revealed by engineering and production, and those in the product found by sales and customers are gradually cleared out.

SMALL-SCALE BLUNDERS — Obviously blunders made in development are far less serious in their effects on the pilot plant scale than if they had happened in a production plant. But that in no wise excuses the temporary or permanent members of the pilot plant staff if they simply blunder ahead thoughtlessly without a careful plan. Far too often the research man abandons his brains at the door of the pilot plant, and because he understands that it is the place to make mistakes, proceeds to make every reasonable error and some utterly unreasonable ones. The plant man and the engineer do the same thing, and the pilot plant operator is the victim of them all.

Troubles sometimes arise because the value and function of the pilot plant are not understood by outsiders or by those temporarily on its staff. Too often the pilot plant is thought of as being an extension of the other fellow's territory reaching out toward one's own, when actually it is an independent entity between the two, belonging to neither and to both.

Design of pilot plant processes which will function adequately is an important study in itself. Unfortunately too little attention has been paid to it, presumably on the assumption that the good sense of all concerned will arrive at a reasonable and effective compromise and that such a compromise will be the thing desired. It may or may not be. The mere fact that it is a compromise does not guarantee its value. Furthermore, the fact is repeatedly made evident that failure can happen quite as readily between laboratory and pilot plant as between that and the full-scale plant. And it is not impossible for a process to succeed in the full scale plant when it has previously failed in both laboratory and pilot plant.

The basic problem of the pilot plant process thus is: to enlarge the laboratory experiments, to shrink the plant operation and to give the intermediate stage some logical and evaluable relation to each. This is by no means easy, but when thoughtfully achieved, it provides vital information on which all members of the policy-forming group of a company can base thought decisions. The practice of the chemical industry certainly points the way for others to follow in the use of this invaluable tool of management and growth.

Small batches of rubber are processed on this pilot plant machine, duplicating in miniature the full-scale operation

PROSPECTING FROM THE AIR

The Airborne Magnetometer, Perfected During the War to Detect Submarines, Has Now Mapped Variations in the Earth's Magnetic Field Over 250,000 Square Miles. Its Purpose: to Reveal Hidden Formations Containing Minerals and Oil

By Homer Jensen and Eugene F. Peterson
Aero Service Corporation

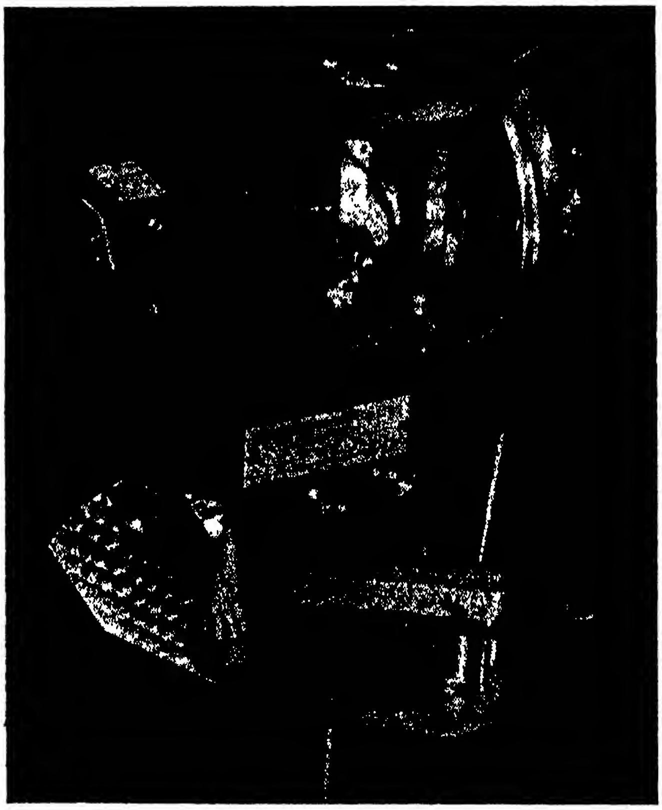
UNTIL recently geophysicists who needed information about the earth's magnetic field in a particular locality sent out survey parties with a magnetometer. Frequently the party had to hack its way through the bush to collect the necessary data. If the area were not too large nor the terrain too difficult, it might obtain a sufficient number of readings in two years. It was slow, expensive work.

Today geophysicists can use a dramatic refinement of this old method—the *airborne* magnetometer. Carried by an airplane traveling at 125 miles per hour, the airborne magnetometer can deliver accurate data to those interested in new oil and mineral resources at a rate of 1000 to 10,000 square miles per month.

Used as a geophysical instrument, the magnetometer is as old as the lodestone. A magnetic compass is itself a simple magnetometer, for it reacts to large bodies of certain ores. As long ago as the 17th century crude compasses and magnetic dip needles were used in the search for ore bodies in Sweden.

The magnetometer is fundamentally an instrument to measure variations in the earth's magnetic field. If the earth were a perfectly homogeneous sphere, its field would range without discontinuity from a minimum at the equator to a maximum at the poles. But the structure and composition of the earth's crust are widely varied, and the variations are reflected in discontinuities of the magnetic field. Accurate measurement of this magnetic field, therefore, yields data which can be interpreted by geologists and geophysicists as guideposts to mineral deposits and geologic structures possibly containing oil.

LITTLE MORE THAN A COMPASS — The magnetometer used by ground survey parties is little more than a compass—a device of magnetized bars rigged with special weights for greater sensitivity. In 1936 it was reported that A. Logachev, a Russian geophysicist, had experimented with an airborne instrument. He employed equipment already used for ground surveys, mounting it on gimbals to maintain its proper orientation in the aircraft. So far as is known, this instrument was never perfected for practical aerial use. Dr. E. A. Eckhardt of the Gulf Research and Development Company, who pioneered in the development of a high-sensitivity instrument in this country, states that the sensitivity of the Russian device was of the order of a rather coarse 1000 gammas.



A coil of wire with a special ferrous alloy core is the heart of this magnetometer sensing element

The gamma is a geophysical unit of magnetic intensity, one gamma being equal to 10^{-5} Oersted. The extremely small quantity involved can be seen in the fact that the earth's magnetic field in the latitude of the U. S. has an intensity of about 50,000 gammas. An automobile at 100 feet gives a signal of two or three gammas. The effect of magnetic bodies varies roughly as the inverse cube of the distance from the body to the detector.

The magnetometer finally became an electronic

device capable of measuring magnetic fields down to the last gamma only in the last few years. Today's instrument, developed and perfected during the war, greatly improved the magnetometer's sensitivity and gave it wings. In flight, the magnetometer registers a continuous profile of magnetic intensity, recording the generalized pattern of an area rather than the scattered point information collected by ground surveys. At its usual mapping altitude (300 to 1500 feet) the airborne magnetometer is remote from local magnetic disturbances which tend to produce false contours.

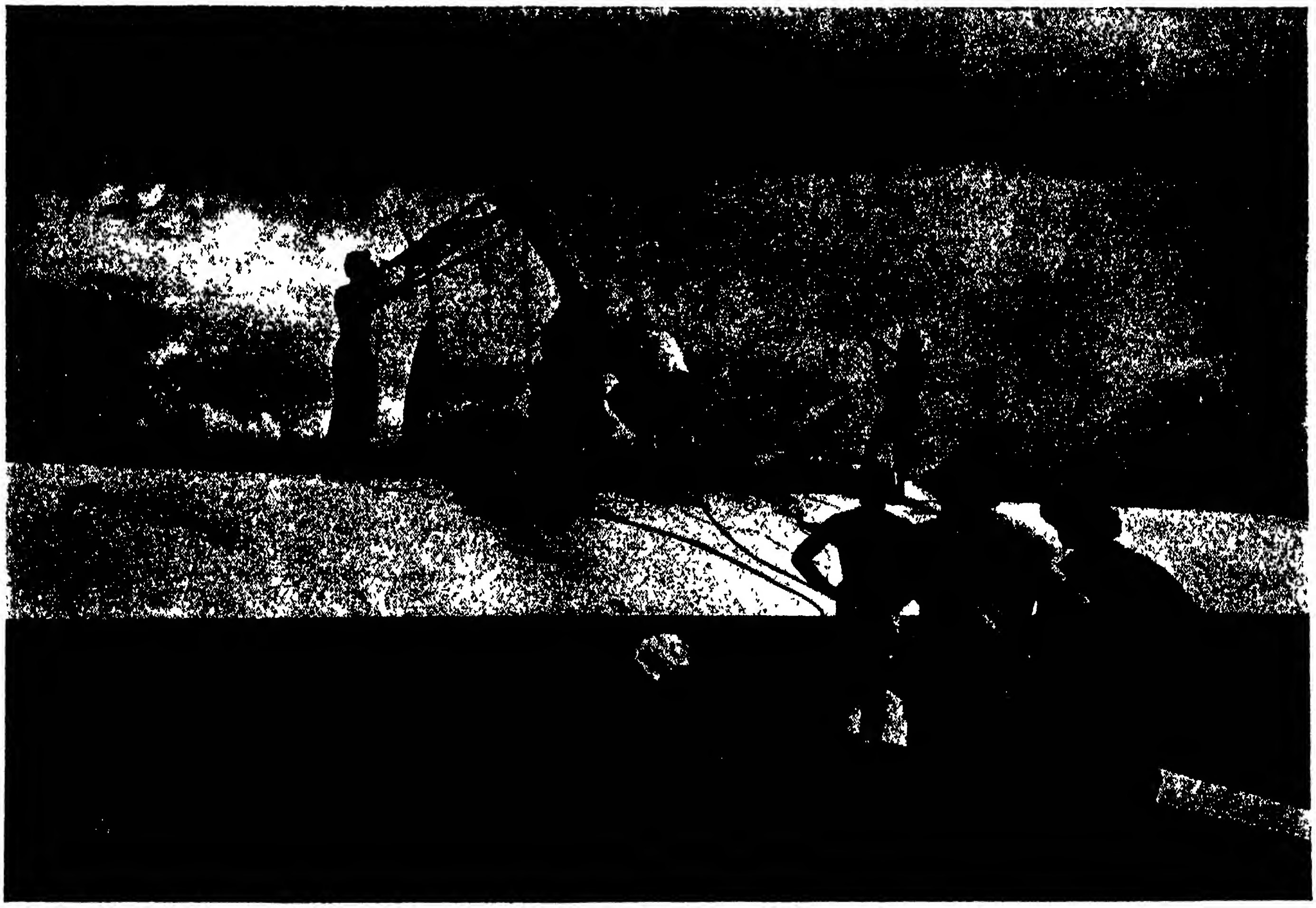
More than a quarter of a million square miles have been mapped by the airborne magnetometer since its first preliminary runs in 1941. It has performed in the Arctic cold at Point Barrow, Alaska and in the heat and humidity of Venezuela. Its operating techniques are now well established.

BAHAMAS SURVEY — A recent survey of the Bahamas area, uniquely complex in its problems, is a good example of how the magnetometer is employed. The Aero Service Corporation of Philadelphia, working for a group of five major oil companies, began the survey in May of 1947 and completed it last month. The problem in this largest of all magnetometer studies was to map an area of 80,000 square miles, of which 90 per cent was shoal water. There were few land points to correlate the magnetometer readings, but these were marked by old and inaccurate charts. Accurate reference by astronomical means was impossible because extreme anomalies in local gravity made it difficult to keep instruments level. These conditions were a large handicap to the precise requirements of the survey: to direct a DC-3 survey aircraft on a grid with two-mile squares within a tolerance of 150 feet. The magnetic records had then to be correlated with an exact record of this flight path. Fortunately the Director of Naval Petroleum Reserves had taken an interest in this problem in 1946 and techniques had been worked out for an airborne magnetometer survey over the Gulf of Mexico. Experience there had proved that the Shoran type of radio navigation was a precise and practical instrument for this purpose.

All the positioning of the Bahamas survey was done by Shoran. From a small number of points which had been related by Shoran to the North American Geodetic Grid, a network of geodetic positions was established for the whole area. Shoran stations were set up near previously established points and their positions accurately determined by conventional surveying. The position of marker boats could then be determined from these stations. The actual position of the magnetometer plane could thus be determined continuously through Shoran, from key geodetic positions.

Two ships 30 miles apart, provided continuous tri-

Erecting a Shoran antenna aboard a flying boat that functioned as a mark-ship during part of the survey



Repairing the sensing element of the magnetometer. The element is housed in a plastics "bird" which trails 100 feet below the plane in flight

angulation for the plane over an area of about 2400 square miles. When one area was completed, one marker ship moved into a new position and became a new station. The survey plane then referred to this new pair of points. The process continued until the whole area was covered.

It is interesting to note that like Shoran, developed by the Army Air Forces for precision bombing, the airborne magnetometer also had a wartime role, in locating submarines. The Bahamas survey plane carried a Shoran transmitter and receiver which operated an indicator to direct the pilot along a rigid flight path. The pilots reported it to be similar to flying an instrument landing system localizer all day long. The question of the plane's altitude presented its own complication. As the weather data available did not permit accurate setting of a barometric altimeter, modified radio altimeter was used to record the altitude continuously. All three elements of the plane's position—one vertical and two horizontal—were thus established. These were in turn correlated with data recorded by the magnetometer.

SUSPENDED FROM PLANE — The magnetometer used in the Bahamas oil survey, built by the Gulf Research and Development Company, was carried in a plastic "bird" suspended by a cable 100 feet below the survey plane. The cable also functioned as an electrical connection between the detector element and the plane's electronic equipment. The detecting element, or flux-gate, of the magnetometer is a coil of wire with a special ferrous alloy core. Its magnetic condition is investigated one thousand times a second by means of an alternating current from the plane. The output signal, proportional to the magnetic field in the locality, travels through the cable to a system of amplifiers in the plane and is fed into a recording mechanism. The recorder keeps a continuous account of the variations of the magnetic field transmitted from the magnetometer detector element.

In oil surveys the recorder traces are broad and sweeping, since oil-bearing rock is non-magnetic and the source of magnetic discontinuity remote from the detector. In mining surveys, the traces are irregular, small and steep, since the magnetic material is nearer the surface and the discontinuities more apparent. As an analogy, the magnetic contours of oil surveys are similar in appearance to the topographical contours of gently rolling country, whereas the magnetic contours over mineralized areas will resemble the topographic contours of hilly, chopped-up terrain.

If the Bahamas survey had been made principally over land, where there is enough distinctive terrain, the mapping would have been done with photographic reference instead of with Shoran. The position of the plane would have been recorded by a continuous strip camera. This camera, gyro-stabilized for greater accuracy, provides an unbroken record of the flight path on a single roll of 35 mm film. The film roll, which is 400 feet in length, records a flight path width of 700 feet over a length of 400 miles. This flight path photo-record is then correlated with the altimeter records and magnetic intensity profiles, as in the case of the Shoran records.

MAGNETOMETER APPLICATIONS WIDENING — The airborne magnetometer is coming into much wider application as an instrument of geophysical exploration. While it is no wonder tool, it has established certain definite advantages for rapid reconnaissance of large areas. In the case of highly magnetic ore bodies such as magnetite and ilmenite, the magnetic intensity maps may say, in effect, "Dig here!" In general, however, the airborne magnetometer's greatest value is in the elimination of unpromising areas and the isolation of points worthy of more exhaustive inspection by surface geology and the use of the gravimeter, seismograph and other instruments.

The great speed and accuracy of the airborne magnetometer was summed up by James R Balsley, Jr. of the Geological Survey, U. S. Department of the Interior, in his report, "The Airborne Magnetometer." Balsley said that in two months, "A four-man crew made a survey of 3170 miles in the Adirondacks with flight lines usually a quarter-mile apart, a total of 11,300 miles of traverse. The cost of an equivalent survey with the dip needle would be 17 times as great and would have required 27 six-month seasons with a four-man crew—about 80 times the period required for the airborne survey. In addition, the ground survey would have been considerably less detailed and accurate."

Large areas now have been mapped with the airborne magnetometer. The U. S. Navy has mapped the Naval Petroleum Reserve No 4 in Alaska, some sections of our Gulf Coast, the Aleutian volcanoes and submarine trench. It is reported that the Navy will employ the magnetometer to survey Bikini as well. The U. S. Geological Survey has mapped sections of Northern Michigan, Utah, Wyoming, Pennsylvania, Minnesota, Maryland and New York. Commercial surveys include sections of Canada, some states of the Middle West, and Southwest, the Bahamas area and parts of Venezuela and Colombia.

The sum of this work is a great body of accurate magnetic data never before available to geologists or geophysicists. From it will come a new insight into the value of magnetic instruments in oil and mineral exploration and new applications for this highly mobile new tool.

SCIENTIFIC AMERICAN'S *Industrial Digest*

NAVIGATION COMPUTER

Electronic Device Automatically Guides Plane in Any Weather

A NEW ELECTRONIC navigator for aircraft will in effect broaden the nation's air lanes at least 10 fold at each flight level, and at the same time make possible split-second timing of schedules under nearly any condition of wind or visibility. This device, called the B-D Computer will not only make it possible to handle more traffic safely, but also will permit greater speeds and eliminate landing delays due to "stacking." Since the automatic instrument makes the proper compensations for wind variables during flight, timing between air ports can be precise. Both the pilot and ground crew will know by pre-determined schedule exactly when each plane will land.

The B-D Computer will prevent crowding of the airways particularly during instrument-flying weather by placing planes flying the same route on various parallel tracks. While planes can be landed safely at 15-minute intervals today, the new instrument will make it possible for the planes to come in within a few minutes of each other.

This instrument, developed by the Minneapolis-Honeywell Regulator Company, derives its name from the information supplied it by radio signals, namely the *bearing* of the plane from a ground radio station of known position, and the *distance* of the plane from this same point

Under present methods of radio navigation only a very limited number of aircraft can fly the same route at the same time The B-D Computer contains an "off course" control which will increase this limit by at least 10 times. Instead of each plane flying directly "down the beam," pilots will be able to set in an "off course" calibration on either side of the beam. Thus, radio ground control might schedule one plane down the center track of the airways beacon system, another plane five miles to the right of the center track and another five miles to the left. All could safely fly the same route at the same time. When given flight directions the pilot need only turn a dial to the designated number of miles off course and the plane will automatically hold that track until it arrives at its destination. The instrument takes into consideration and compensates for head, tail or cross winds and other factors.

Designed to make use of recently developed means of aircraft radio transmission, the computer takes signals from ground stations and relays them through the regular automatic approach coupler of the auto-pilot This coupler is the device currently used for automatic landing. The signals are then routed to the autopilot to fly the plane automatically on the course set for the plane.

The computer receives signals from two different radio transmitters. One of these signals is received from the ODR (omni-directional range) transmitter and gives the direction of the plane in flight from the radio ground station. The other signal is picked up from the DME (distance measuring equipment) transmitter and it gives the distance of the plane from this same location. The present range of DME is limited to 100 miles. In flight, the off-track deviation is shown to the pilot on the regular cross pointer (blind landing) instrument, which is calibrated to read with the same sensitivity as when on automatic landing beams at 10 miles out from the air strip.

In preparation for a B-D navigated flight the pilot draws a straight line from his point of departure to point of destination on a regular air map and then draws a line measuring the perpendicular distance from his flight course to the location of the transmitting stations. He also measures the distance from the intersection of the two lines previously drawn to his destination, which is

The B-D Computer being tested by a Civil Aeronautics Administration engineer

called the on-track distance, and further measures the course angle with respect to north. This gives him three different figures, two of which are in miles and the third in degrees. The pilot sets up the computer by setting the appropriate dials to these numbers, and then turns on the autopilot. This also turns on the computer. He tunes in the radio stations providing the necessary information and is ready for take-off. The computer now is receiving two kinds of information, one a bearing signal from the omni-directional range and the other a signal from the distance measuring equipment.

In flight, the cross pointer instrument is switched to the navigation computer so that the meter now gives the flyer off-track information, while a separate dial gives distance to destination. He can either fly manually by watching the cross pointer needle as he does now on instrument approach landings, or he can switch to automatic control, so that the computer will fly the plane through the automatic pilot.

It is possible to provide the necessary settings in pre-set form so that all of the data for a routine flight covering long distance travel can be set in before take-off. The change from one ground reference station to another can then be made automatically as the flight proceeds.

It is also possible to add an automatic estimated time of arrival dial which can serve as guidance to the pilot in making good his assigned time schedules. This dial will not only tell the pilot when he will get to his destination if he holds his present airspeed, but also will enable him to adjust throttles to insure scheduled arrival. A further provision of this device will enable ground control to change assigned arrival time while the plane is in flight. In such an instance, the pilot need only set a dial which will tell him the airspeed required to meet his new schedule. The device takes into consideration such factors as head and tail winds, since the operation is based solely on geographical position.

Another attractive possibility in facilitating the keeping of schedules, is an off-schedule distance indicator. In this case the schedule position of the plane is computed continuously on the basis of the scheduled ground speed. The difference between schedule position and actual position is continuously indicated on the horizontal needle of the pilot's cross pointer instrument, so that the pilot can adjust speed manually to maintain his assigned schedule. It is intended that the off-schedule distance information will also be applied to an airspeed control system, operating through autopilot and throttle control, to keep the airplane automatically on schedule.

PIERCING HOLES

On Stamping Press Is Aid To Interchangeability

INTERCHANGEABILITY of parts is an essential factor in keeping today's assembly costs down, and the use of mass-produced precision stampings is one way to achieve interchangeability. A rapidly growing practice which extends these advantages is the piercing of holes on stamping presses, simultaneous with the stamping operation, rather than drilling or punching the holes.

Interchangeability is often difficult to achieve when many holes in a single complicated shaped piece have to be drilled or punched individually. The new technique permits the piercing of such holes, with diameters less than the thickness of the blank or with tolerances under 0.001 inch, at the same time as blanking and before forming. The holes may be round or shaped, and vary in size from 1/32 inch to several inches in diameter, in many instances the diameter of the holes being only a fraction of the thickness of the metal pierced. In some cases as many as 400 holes are being pierced in a single, comparatively small stamping.

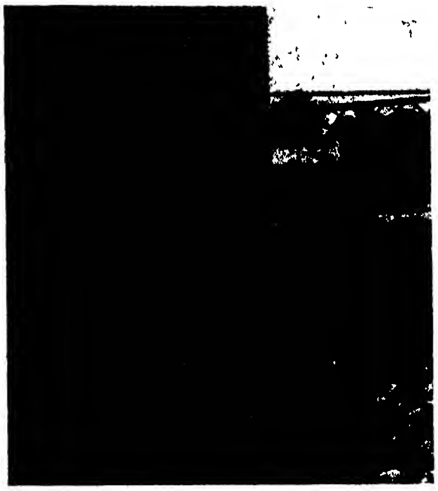
All types of metals used by stampers can be pierced successfully on stamping presses using tools and dies of proper design. Outstanding product applications to date include brass carburetor disks, pure nickel spinnerettes, brass ignition tubes, steel railway car hopper plates, heavy-wall aluminum tubing, copper end plates for motor rotors, and so on.—*F.P.P.*

BEVELING CONCRETE

With Rubber Strips Gives Smooth Finish, Cuts Building Costs

A NEW METHOD of forming bevels and decorative grooves on concrete surfaces by means of rubber strips attached to the forms—instead of conventional wood strips—is said to produce a smooth finish free of blemishes. The rubber strips can be re-used many times, resulting in lower construction costs.

These strips, developed by the United States Rubber Company, will be produced in various shapes and sizes for bevels and also decorative treatment. They are attached to the form with a waterproof adhesive, and can be removed easily from the mortar without chipping.



Rubber strips attached to the forms produced these grooves and bevels

RADIANT BASEBOARDS

Prove Their Advantages in University Tests

WARMER floors for basementless houses without resort to experimental types of heating, and better distributed, cleaner, and inconspicuous hot water heat for all homes were forecast recently by Professor Warren S Harris of the University of Illinois.

Speaking of tests with "radiant baseboards" in the Institute of Boiler and Radiator Manufacturers' research home at the university, Professor Harris said that this system has proved a way to provide warmer floors, and that it gives much less difference between floor and ceiling temperatures, is convenient in being both inconspicuous and in not interfering with furniture placement, and is outstanding in cleanliness.

The radiant baseboard, a hollow cast-iron baseboard, placed at the bottom of the outside walls in a room, is painted to match the wood trim at the base of the other walls. Hot water in the baseboard is supplied from a conventional home heating boiler through concealed pipes.

By concentrating heating effect along the base of the coldest wall, the radiant baseboard produces warm floors. "This attribute is most important for basementless houses in which cold floors are particularly prevalent," Professor Harris said.

Comparing radiant baseboards

with conventional small tube radiators, on the basis of tests thus far conducted, the heating engineer said:

"Drafts were not experienced with either radiant baseboards or small-tube radiators.

"Radiant baseboards produced warmer floors and cooler ceilings than did the small-tube radiators, a characteristic which makes them adaptable to basementless houses.

"From the 60-inch level to the floor, the inside surfaces of the wall along which the radiant baseboard was installed were warmer than the room air at the 30-inch level of the thermostat, whereas these surfaces were cooler than the room air when the small-tube radiators were used.

"The radiant baseboard was clean in operation.

"The radiant baseboard blended with the wood trim of the room in appearance, and did not interfere with placement of furniture in the room."

ANTI-FRICTION BEARINGS

With Cartridge-Type Housings Facilitate Reconversion

When machines and other equipment are redesigned for assignment to new tasks, it often is necessary to locate shafts where ordinary hangars or pillow blocks would be difficult to mount.

Anti-friction bearings in cartridge-type housings are solving the problem. Some housings are made to be force fits in plain holes which may be drilled in a machine frame or any structural member. Others have double plate flanges with holes provided for fastening screws. Still others have threaded extension housings so arranged that if turned on a fitting steel shaft the bearing housings may be positioned for shaft alinement, or if the rods are turned the housings may be backed away and so act as take-up units for belts or chains.—*E.L.C.*

EMBOSSING THERMOPLASTICS

By Four-Step Process Is Quick and Simple

Embossing acrylic and other thermoplastics by a recently developed method depends for its success upon a new casting material called Ceramite. Both Ceramite and the associated technique were developed by the Furane Plastics and Chemical Company. Only four steps are involved in this embossing process:

1. A clay model, or equivalent, is prepared with the design that is to be embossed on the thermoplastic sheet.
2. Ceramite is poured over this model and allowed to set for about 30 minutes before it is removed from the model.
3. The Ceramite casting is cured for several hours at room temperature.
4. A warmed thermoplastic sheet, backed with a rubber pad, is placed over the Ceramite casting and pressed firmly against it. The pad acts to force the plastics into every detail of the design.—*C.A.B.*

"IMPOSSIBLE" MACHINING

Of Alloy Casting Is Done With Cemented Carbide Tool

Considered practically "un-machinable," castings of Ni-Hard—an alloyed, heat treated white iron with a Brinell hardness ranging from 550 to 700—are generally finished to shape by grinding.

Ni-Hard, however, can be machined with tools of cemented carbide. The Ni-Hard six inch mine pump casing shown in the accompanying illustration is being finished on a boring mill at the plant of Barrett-Haentjens and Company with Carboloy Grade 44A tools. Rough cuts as heavy as .075 inch are made with a feed of .020 inch, on a 20 inch bore of the six inch pump casing, using a speed of 5¼ revolutions per minute, which is equivalent to a 27½ foot per minute cutting speed. Finishing cuts are made with a .015 inch depth of cut and a .020 inch feed. Speeds of approximately 16 feet per minute are used on such special cuts as turning a 45 degree angle on the face of a casing, or boring the inside diameter of the Ni-Hard "wearing plates."

Machining these casings requires 16 hours with Barrett-Haentjens' carbide setup, compared with about twice this time for grinding.

Rough cuts as heavy as .075 inch can be made

NATION'S COAL RESERVES

Can Last 1500 Years, Says Bituminous Expert

Coal reserves in this country are so enormous that they can supply all this nation's requirements for the next 1500 years, Dr. Harold J. Rose, vice president and director of research for Bituminous Coal Research, Inc., stated recently. This applies to requirements for heat, light, power, transportation and the smelting of metals, all liquid and gaseous fuels, and most synthetic chemicals, at the present rate of consumption, with allowance for conversion efficiencies, he said.

"The world has spent more of its mineral wealth in the last 40 years than in all preceding history," he continued. "Production has been particularly great in the United States, so that we already are a 'have-not' nation, or are rapidly becoming one, with respect to many important minerals."

The outstanding bright spot in this serious situation is the enor-

mous coal supply, amounting to about one half the world's known reserves, according to Mr. Rose, who went on to say: "Coal has been, and will continue to be, this country's most important mineral resource, and the foundation of its expanding industrial production. Technical developments have been so rapid that coal can now be used to produce almost any type of solid, liquid, or gaseous fuel or synthetic chemical product."

In contrast to the large coal reserves, Dr. Rose continued, the proved reserves of petroleum and natural gas in this country would last only 8½ years if they could be produced and used fast enough to supply their present markets, and to take over all present coal uses at the same Btu efficiency.

These facts are causing a great increase in the support being given to coal research, he pointed out, by the coal industry itself, by federal and state governments, by the petroleum, gas and chemical industries, and by equipment manufacturers. Expenditures on research and engineering development work closely related to coal are $15,000,000 or more annually, in this country, with large additional expenditures in England and other countries.

TABLE-TOP TUBE MODEL

Simulates Electrons, Tube Elements on Grand Scale To Test New Designs

A VACUUM tube model constructed on a highly magnified scale is aiding engineers to develop more powerful, more efficient vacuum tubes by reducing the tube-design testing period from three or more months to a single day. This model electronic tube is a rubber-topped table where rolling bronze balls about the size of BB shot play the rôle of electrons speeding from one end of a tube to the other.

"By using this grand-scale model, we can produce approximate replicas of most kinds of electronic tubes," explains R. O. McIntosh, electronics engineer of the Westinghouse Research Laboratories, where the model is being employed. "We can check the internal design of a tube in one day, whereas former mathematical trial and error methods of testing consumed about three months to do the same job.

"Even to change the design of a single tube part used to require a whole day. Now it can be done in five minutes."

To test a tube design, research men stretch a thin piece of rubber—measuring only a few hundredths of an inch in thickness—over an area about the size of a small dining room table. The electrons are simulated by the small bronze balls which weigh only 1/14 ounce apiece.

"The 'electrical' push and pull necessary to propel these over-sized 'electrons' is provided by creating hills and valleys in the rubber surface of the table," Mr. McIntosh explains.

"Real electrons are repulsed by negative charges and attracted by positive charges. On the table, attractive forces are represented by the downward slope of a hill and the upward slope acts as a repulsive force. By proper arrangement of hills and valleys we can steer the ball, speeding it up or slowing it down. Then by measuring the time it takes for the ball to roll from one part of the table to another, we can calculate the speed of actual electrons in such a tube. This tells us the voltage needed for this part of the tube."

The table model can also reveal how far apart the tube elements should be spaced and what their shape would be. By actually reproducing in wooden blocks various shapes and sizes of electrodes—round, pointed or square it is possible to learn which arrangements gives the greatest output of electrons, and delivers them to the most useful place.

Slight hills and valleys in the thin rubber sheet simulate electrostatic attraction and repulsion as the white "electron" speeds from the "cathode" (at the man's hand) to the "plate" (lower left corner). This table-top model is aiding research engineers develop more efficient vacuum tubes of all types

IDLE WELDING MACHINE

Saves Time and Money In Coach Seat Fabrication

AN EXCELLENT way—believe it or not—to cut production costs on some jobs today is to buy machine tools which have so much productive capacity that they stand idle most of the time. A few years ago, such an idea—applied to a medium

sized company with relatively limited production runs—would have been called ridiculous. The Heywood-Wakefield Company, however, has an excellent example to prove its practicality.

Heywood-Wakefield makes, among other things, coach seats for buses, railroads and so on. These seats are supported on the aisle side by stainless steel pedestals formed from 18 gage sheet stainless. These were formerly fabricated by gas welding the seam that forms the oval. It took 10 minutes, roughly, to complete one of these welds. This was followed by grinding.

Some time ago, however, after discussing the problem with Progressive Welder Company, the fabricator re-designed the pedestals slightly and installed a Progressive seam welder to fabricate them. The machine, Heywood-Wakefield knew, had a production capacity far in excess of anything they could use. It could turn out in an hour what it took a gas welder a week to weld up.

As a result, the welder operates only two weeks out of every eight or nine. But after the first few weeks of operation, the machine had already paid for itself—largely because it doesn't cost anything to run a machine when it stands idle (six or seven weeks idle out of every two months in this case). Since then, the machine has been saving enough to regularly pay the wages of 10 additional workers on other jobs

The machine is equipped with a special moving fixture, also designed by Progressive, which carries the pedestals through between the welder wheels. The fixture has a collapsible copper mandrel which serves to hold and locate the pedestal during welding, the collapsible construction permitting quick removal of the finished parts. Seam welding has also practically eliminated all grinding at the welds, while avoiding destruction of stainless steel qualities—something difficult to do when gas welding.

The welder is so designed that if the occasion arises, the wheels can be removed and the machine used for either press or spot welding of other parts.

PLASTICS GAS PIPE

Extruded Tubing Replaces Steel In Home Installations

EXTRUDED plastics tubing is replacing steel gas pipe in home installations where it conducts fuel gas from the gas main to the customer's meter.

The one-inch cellulose acetate butyrate tubing used for this purpose has several advantages over steel pipe: it is readily available, whereas steel has been in short or unstable supply for years; it is light in weight and easily handled; fewer men are needed to install it than are required for conventional pipe; shipping and installing costs are lower; it can be bent on the job and requires little equipment for joining; and it resists deterioration in most soils. Tests made by the Southern California Gas Company revealed that these pipes could be used almost everywhere, except where they might come in contact with refinery gases and other products of oil refining. They are laid only in mild soils, not in rocky ground (since rocks could pinch the tubing together when the excavation was filled and tamped) and are placed at the standard depth of eighteen inches.

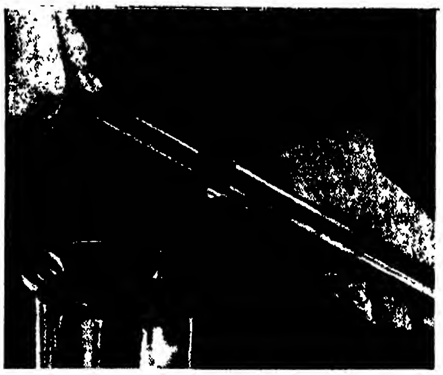
Joining this pipe is simple. The two ends of the one-inch outside diameter pipe, made from Tennessee Eastman Company's Tenite, are coated with a solvent cement and joined A sleeve of one-inch inside-diameter tubing, similarly coated on the inside, is then slipped over the joint, and the three pieces are "welded" together at once. Cement is colored for easy visual inspection of the joint.

Joints are covered with grease, two wraps of cellulose acetate sheet, and one of kraft paper. This makes a suitable shield for mild soils, and does away with the time and bulky equipment necessary for preparing the hot asphalt shields which are used on steel-pipe joints

Gradual bends in the flexible tubing are easily accomplished on the job. Right-angle bends are made in accordance with company rules with pre-fabricated right-angle sections sleeve-jointed to the tubing.

Joints at the "service T," where the plastics pipe meets the steel gas main, and at the "riser," where a copper tube joins the pipe to carry gas into the house, are made with Dresser fittings—pre-assembled iron joints in the shape of hollow dumbbells A gas-tight assembly is made by tightening the ends of the Dresser fitting, which contains rubber glands in either end, around the Tenite pipe, metal T or riser

To make a connection, a standard metal T is welded, crossbar down, to the steel main. (If a mechanical service T instead of a welding T is used, welding is not required—meaning one less man on the installation crew.) The leg of the T which is at right angles to the main is assembled with the Dresser fitting, as is the end of the plastics gas pipe. A similar fitting is used on the other end of the Tenite pipe, and a copper tube completes the connection to the meter.



Joining two lengths of plastics gas pipe

The main is tapped by means of a special tool inserted through the vertical crossbar of the T. Afterwards, the top end of the T is plugged, and gas flows from the main up through the T, into the Tenite pipe, and to the customer's meter.

Tenite pipes and joints are made to stand up under a maximum safety pressure of thirty pounds per square inch, although in tests they are said to have withstood far higher pressures.

Thus far, Southern California Gas Company has made about 500 installations (about 40,000 feet of plastics tubing). For the time being, the plastic tubing will be used only for domestic standard services which involve just one size of tubing and fittings.

BRIGHT BARREL FINISHING

Achieves Great Cost Reductions In Small Parts Production

SOME OF the more recent forms of barrel finishing (for example, Roto-Finishing, developed by Sturgis Products Company) have not only resulted in brighter-honed parts than can normally be produced in bulk at high production rates, but also in cost reductions in the neighborhood of 90 per cent in some cases.

One manufacturer of fishing reels has applied the process to several different types of parts, with the following specific cost savings (to show the range): A stainless steel plate that originally cost 23.1 cents per hundred to buff, is now barrel-finished for 21.0 cents, with a saving of 9 per cent in finishing costs. Again, a brass bushing, formerly buffed on a wheel, originally cost 34.1 cents per hundred to buff. With the barrel-finishing process, the cost has

dropped to 1.3 cents per hundred, a saving of 96 per cent. And, finally, a brass stamping that previously cost $1.41 per hundred to buff, now entails only 3.9 cents per hundred, a saving here of 97 per cent.—*F.P.P.*

SUGAR DERIVATIVE

May Become Ingredient Of Resistant Varnishes

Research now under way at the United States Department of Agriculture's Eastern Regional Research Laboratory may prove the merit of allyl sucrose, a chemical derivative of ordinary sugar as a varnish resin.

Over two years ago, the Laboratory developed allyl starch, similar except that the raw material is starch instead of sugar, which dissolves in standard varnish solvents. Applied to surfaces of wood, paper, or metal, the varnish leaves a smooth, high-gloss coating which is resistant to solvents, acids, alkalies and hot oils. Cured at 175 degrees Fahrenheit, for a short time, the coatings are thereafter resistant to temperatures up to 400 degrees, Fahrenheit.

An experimental run made with sugar at that time looked promising, so its possibilities are now being further explored. An early drawback was the necessity of distilling the allyl sucrose under high vacuum in order to get a clean product; that has been solved, and now only a water wash is necessary.

Allyl sucrose has all the virtues of allyl starch, and an additional one as well: It is more compatible with varnish solvents. Raw materials for its synthesis are cheap enough so that the resin may eventually compete with ordinary varnish resins.—*H.C.E J.*

ALUMINUM WIRING

Performs Well, Is Becoming Generally Accepted

Insulated aluminum electrical wire has advanced beyond the experimental stage to become a permanent product of the electrical industry, according to H H. Weber, of the wire and cable department of United States Rubber Company.

Aluminum wire was frequently employed as a substitute for copper during the severe copper shortage of World War II. Its performance has been so satisfactory, says Mr. Weber, that it is winning permanent acceptance in electrical circles.

Insulated aluminum wire has been used considerably in airplanes, where its lighter weight increased the range and payload of planes. Now United States Rubber Company is making large quantities for homes, factories and other buildings.

"Aluminum is in plentiful supply and economical to produce," said Mr. Weber. "Deposits are to be found in most of the earth's crust. A shovelful of common clay may contain as much as a pound of aluminum. Aluminum has the highest electrical conductivity of any metal on a pound-for-pound basis. It has high strength and good resistance to the elements. The fact that aluminum wires and cables are being used in large quantities in aircraft, where safety and reliability are paramount, is a strong indication of their suitability for rugged, reliable service. The lighter aluminum wire permits a substantial reduction in the weight of planes. This application puts the wire to a severe test, with repeated cycles of heat, cold, moisture and vibration."

Through intensified research the United States Rubber Company in co-operation with aluminum producers has developed new techniques and materials for soldering and insulating aluminum, Mr. Weber explained. He pointed out further that Underwriters Laboratories recently approved aluminum conductors for homes and industrial buildings, and they have been recognized for many years by the National Electrical Code.

WHIRLING TESTER

Pilots and Instruments Subjected To High Accelerations

Powered by an electric drive system, a new machine now being built by the Navy will subject aircraft pilots and instruments to high accelerations, equivalent to those experienced in actual flying. The new accelerator will provide radial accelerations up to 1290 feet per second per second, or 40 times the acceleration of gravity. The rotating system, developed by the General Electric Company, will be driven directly by a vertical motor rated 4000 horsepower and capable of developing a maximum torque of 1,700,000 foot pounds.

Acceleration patterns of aircraft in flight maneuvers will be simulated by the drive, which utilizes an amplidyne exciter in combination with an electronic control system, which in turn will be responsive to a program control. Emergency stopping will be accomplished by dynamic braking, the machine being brought to a final halt by pneumatically-operated friction brakes.

HOLE DRILLING "CANNON"

Fires Punch Through Steel Rail To Reduce Boring Time

Workers who tend the 135 miles of railway track in the Ford Motor Company's Rouge plant now are equipped with a "cannon" that will shoot holes in steel rails. Called a velocity power-rail punch by the Mine Safety Appliance Company which manufactures it, this 45-pound, portable industrial firearm is loaded by placing the cartridge behind a punch of desired diameter. The firing pin is then attached and the "cannon" fired by a tap with a light hammer.

The explosive force drives the punch through the steel rail, leaving a clean, perfectly round hole. This eliminates the time-consuming job of drilling holes in rails when laying track.

Firing a cartridge slightly larger than .45 caliber, the punch is capable of shooting holes up to one and one-half inches in diameter in three-quarter inch steel.

PLASTICS ON CANS

Improves Appearance, Permits Re-sealing Containers

Two examples of plastics' use in the can field offered by the American Can Company indicate that synthetics may be of considerable value in improving both appearance and performance.

The first improvement involves the use of a thermoplastic seal to replace solder on the side seam of cans. The advantage of this change is that containers sealed up the side with plastics may be fully decorated around the outer wall by lithograph. The half-inch wide strip of solder on soldered cans cannot be overprinted.

The second improvement is a new type closure which can be re-sealed after the can has been opened. The moisture-proof seal is achieved by an interrupted thread-type cover having a ring gasket located inside the indented outer edge of the cover where it fits over the top of the can body. This gasket, which helps to lock the cover tightly in place, is made of paper impregnated with a wax and a thermoplastic resin. The re-seal can was specially developed for American Home Foods, Inc.

New Products

FUEL SYSTEM CLEANER

Gums, Tars Are Dissolved and Burned with the Fuel

A NEW TYPE of liquid fuel system cleaner is designed to dissolve and eliminate formations of gums, tars and other dangerous binders that are directly responsible for a large percentage of power stoppage and maintenance expense. This cleaner reforms all soluble hydrocarbon binders into a liquid which burns with the fuel, while rendering free all insolubles into a colloidal suspension. Applied either as a reconditioner or as a preventive simply by pouring into the fuel tank, it functions equally as well with oil, gasoline, kerosene or fuel oil systems. This includes every type of engine, power unit or fuel burner.

This product, called Tank Kleen by its manufacturer, the Celco Corporation, is claimed to be harmless to metal. It eliminates condensation and moisture from the fuel system, prevents freezing of lines in cars during the winter and improves starting summer and winter and aids in freeing sticky valves and cleaning carburetors without removing them. In the shop it does a fast and thorough job of reclaiming clogged metal parts and carbonized fittings.

BATTERY TESTER

Hearing Aid Cells Checked Under Full Load for More Accuracy

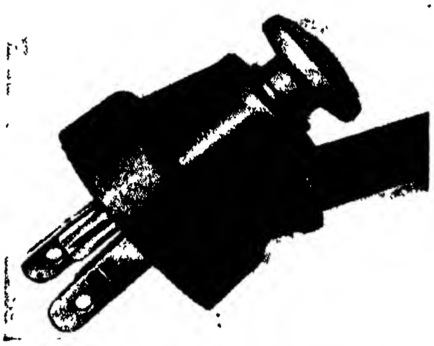
COMPACT and reliable, a new battery tester was designed for checking hearing aid batteries. The device was developed by International Instruments, Inc. in close collaboration with the hearing aid industry. It is designed to test hearing aid batteries of all types and it is claimed that it is the only hearing aid battery tester on the market which checks batteries under full operating conditions for greater accuracy. The compact design of the tester is made possible through the use of the one inch miniature precision movement and the scales are clear and easily read. The unit is housed in a plastics case and is supplied with a leather carrying case

Tester checks all hearing aid batteries

LOCKING PLUG

Touch on Plunger Fixes Prongs Firmly in Receptacle

FITTING any standard power outlet, a new plug locks firmly in the receptacle at the touch of a finger. Pressure on the plunger attached to a sliding wedge forces the prongs of the plug against the contacts of the outlet locking the plug and forming positive contact even in a badly worn receptacle. The plug is unlocked merely by pulling out the plunger. This device, marketed by Neoline, Inc., as the Neolock "105" Locking Plug, is approved by the Underwriters' Laboratories and can be easily installed on all types of electrical appliances.



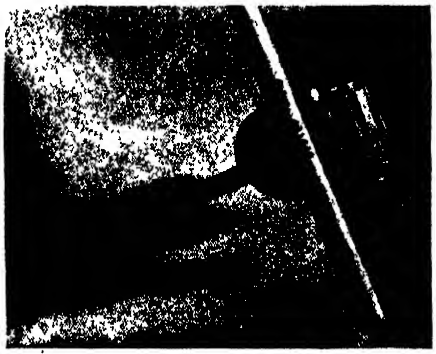
Pressing the plunger locks the plug

ELECTRIC BRANDER

Wood or Leather Permanently Marked by High-Speed Iron

ELECTRICALLY heated, a brander is intended for high speed burn-marking of trademarks, signatures, special designs, lettering and so forth on either flat or round surfaces of all types of wood and leather products. Designed primarily for use in an arbor press, bench press or drill press, the unit can also be used effectively by hand when desired.

The interchangeable type used in this high-speed branding iron, a product of New Method Steel Stamps, Inc., is of a special bronze alloy for quick heating and the lettering or design is burned into the wood or leather the instant contact is made. A dovetail clamp holds the interchangeable type rigidly in place. There is a ½ inch round hardened steel shank on the back of the heating element for fitting the unit into a press. The heater works from any 110-volt socket. The heating element itself is so cast into the head of the brander as to be integral with the unit. It is claimed that this method of construction permits the heater to stand a lot of abuse without failure.



Brander's heater operates on 110-volts

A wide variety of designs and styles of lettering can be furnished with the basic heating element and type holder

ELECTRONIC AMPLIDYNE

Maintains Pre-Set Speed Regardless Of the Load Condition

CONSISTING of a high-gain balanced D.C. electronic amplifier and a motor amplidyne, a new control unit is useful in many types of motor control where precise regulation of current, voltage, and speed is necessary.

Designed for use as a regulated adjustable-voltage power supply for D.C. motors up to one and one half horsepower, and as a regulated exciter for larger adjustable-voltage drives up to 200 horsepower, the new electronic amplidyne has an output of 1½ kilowatts, 250 volts. It is arranged for use on either a 220- or 440-volt, 3-phase, 60-cycle power supply.

The electronic amplidyne makes possible a speed range of 20 to 1 or greater. It maintains speed closely at any setting, regardless of load conditions. It assures smooth, rapid acceleration, and reduces starting shock on the driven machine by means of current limit control of acceleration and stalled current.

Quick stopping without undue stress to motor or driven load is provided

by suicide braking utilizing current limited regeneration. The equipment satisfactorily maintains speed on overhauling loads where the motor is required to absorb power and act as a brake during part of the loading cycle. It is readily adaptable to programming and processing control.

Design features of the unit produced by the General Electric Company, include a completely balanced amplifier which is insensitive to line voltage changes; an industrial electronic amplifier with hinged panel which provides easy access to all parts and connections; a circuit which is easily adjusted for various operating conditions; and a locking device which maintains settings once the circuit has been adjusted. Double end ventilation is provided.

WIRE RECORDER

New Machine Coils Recording Wire In Small Magazine

A new wire recording device eliminates handling of the wire with a wire cartridge which can be plugged in. The cartridge records 30 minutes of speech or music on half a mile of stainless steel-brass wire and may be played

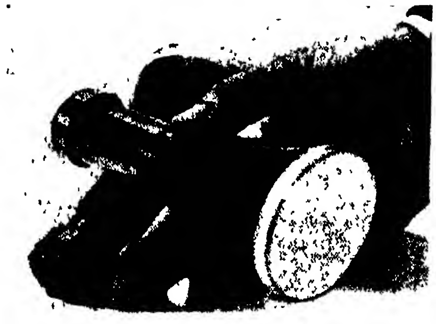
Wire magazine is easily plugged in

back immediately without rewinding. This latter feature is made possible by the fact that the cartridge contains two lengths of permanent wire, wound on four spools. The wires wind, unwind and rewind themselves. Another feature of the recorder, manufactured by RCA-Victor, is a timing device calibrated in minutes which permits the user to determine the exact location of recordings on the wire. Without requiring a separate operation to "clean" previous material off the wire, the recorder automatically erases previous sounds as a new recording is being made.

MIDGET RAY TUBE

Suited For Use in Television Servicing Equipment

Said to provide improved electron-optical characteristics, particularly at the screen edge, a new cathode ray tube has a flat face, and short over-all length. Designed for oscilloscope use, the tube has improved cross-talk characteristics between deflection-plate pairs, and is well suited to the require-



Tube's over-all length is 6⅛ inches

ments of unusually small, light-weight service equipment needed in television installation and maintenance work, according to the manufacturer, the North American Philips Company, Inc. Length of the tube, designated type 3QP1, is only 6⅛ inches and face diameter is 2¾ inches. The tube utilizes P1 (green) phosphor, and has electrostatic focus and deflection.

GROUP TELEPHONE

Device Does Not Require The Use of Headsets

Making possible group telephone conversations without the use of conventional extra headsets, a device recently developed quickly converts a standard French telephone into a microphone and loud speaker. Called the Jordaphone, the new device consists of a small console and a microphone. When the user wishes to change his telephone to a group conversation instrument, he places it in a recess in top of the console. Several people may then speak into the microphone and return conversation is heard on the speaker.

The Jordaphone, manufactured by the Jordanoff Corporation, is not directly connected with the telephone line. Telephone conversations are carried on through it by way of the magnetic fields surrounding the transmitting and receiving ends of the standard instrument. Impulses from the telephone receiver are picked up by a coil in the

The device permits the entire group to take an active part in the conversation

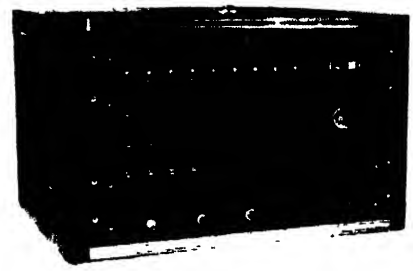
console and amplified. The voice of the user speaking into the microphone is cut off from the amplifier so that only his natural voice is heard.

Power for the device is supplied from a regular electric outlet. Its total weight is 80 pounds.

INTERVAL TIMER

Accurate Measurements Down to Less than A Microsecond

An interval timer for accurate time measurement will measure intervals in steps of 0.625 microsecond. The instrument, manufactured by the Potter Instrument Company, will register directly intervals up to one second. Longer periods can be recorded by using an



Timer indicates by neon glow lamps

external counter to record the number of times the cycle is repeated.

Originally designed to meet the requirements of projectile velocity measurements, the prototypes of this unit, called Model 450, are currently in use in many government proving grounds.

The interval timer is actuated by positive pulses which can be easily derived from detectors such as photoelectric equipment and closing contacts. The time base included in the instrument consists of a 16 Megacycle crystal oscillator. The oscillator, electronic switch and counter decades are made up as individual units which plug into the chassis. Indication is by means of neon indicator glow lamps.

GLASS GLOBULES

Replacing Sand in Plaster Mix Cuts Weight Two-Thirds

Weighing only 12 pounds per cubic foot as compared with sand's weight of 85 pounds per cubic foot, a new light-weight building material, formed of little glass globules, is "popped" by intense heat from raw perlite ore, and is ideally suited, as one of its uses, to replace the sand in plaster. In the construction of an ordinary seven-room house, with its 700 square yards of plaster, this material, product of Dant and Russell, would cut the weight of the plaster from 21,000 pounds to 7000 pounds, an elimination of seven tons of useless weight.

Besides this reduction in weight, plaster containing this material, known

as Dantore, resists the checking and cracking of plaster common in houses which have settled even slightly. The little glass globules and the gypsum are more flexible in adjustment to the stresses of settling. In addition to its light weight and greater flexibility on walls, it also offers a considerable degree of insulation against heat, cold and noise.

AUTOMATIC DISINTEGRATOR

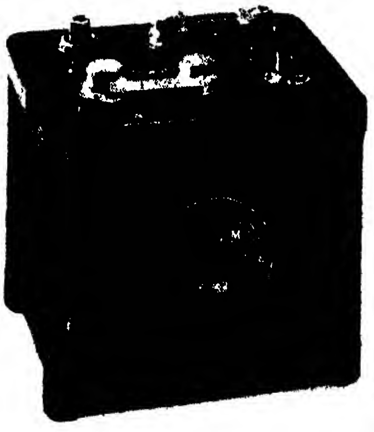
Broken Taps or Drills Are Removed Without Damage To Casting

ELECTRODES are used in an automatic disintegrator as the vehicles to remove taps, drills, studs, reamers and so forth from die sections or castings of hardened steel, brass, bronze or almost any other alloy. This is accomplished without heating or distortion of the casting or machined part. Once adjusted, the disintegrator will complete its operation without any further attention, and one man can keep four or five disintegrators going Broken number two taps up to one inch in diameter are easily removed An ordinary ½ inch tap is disintegrated in seven or eight minutes. Electrodes several feet in length are available for deep holes. This disintegrator, manufactured by the Ansaldi Tool and Engineering Company, is of the revolving head type which can be swiveled to any angle or compound angle. It can be used horizontally, up-side-down, to a height of seven feet or close to the floor. The standard unit is equipped with casters, but a model is also available for use on a bench and another model is adaptable to drill press operation.

DEMOUNTABLE BATTERY

Unit Is Easily Disassembled Into Its Components

FULLY demountable, a new automobile battery can be taken apart, repaired and reassembled in 15 minutes with an ordinary pair of pliers Known as the NuForm Demountable Battery, it contains no hidden sealed parts and it can be completely disassembled into its components. The box, the covers for the cells, the posts, terminals and connecting links are designed for long and dependable service. Other parts can be quickly replaced. Another feature of the battery, manufactured by Associated Battery Assemblers, is the cushioned suspension of the plates from the covers of the cells. This prevents injury from shock and vibration which often occurs when plates rest on the bottom of the battery. It is also claimed that the unconventional design and construction of this battery eliminates leakage, corrosion and sulfation around the terminals.



Cut-away view of battery shows cushioned suspension of plates from cell covers

ANNULAR MARKER

Permits Stamping of Standard and Variable Data Simultaneously

EMPLOYING a combination of a solid stamp and interchangeable type, a new stamping device for annular marking permits stamping parts like gears, bushings and sleeves around the radii with such standard information as the part number and/or a trade mark, together with additional variable data such as a heat treat code, the date or a batch number, all in the same marking operation. In addition to lending itself to fast, accurate hand stamping, the new marker also has a press mounting adaptor permitting it to be used on practically all types of presses (including manual presses) for machine stamping.

The marker may be used as hand stamp or adapted to many types of presses

The new marker, product of New Method Steel Stamps, Inc., consists of a mounting adaptor, and a bushing stamp carrying the standard information which is mortised to take interchangeable characters for the variable data, all held together by set screws. The set screws that hold the bushing stamp in place engage a V-groove in the adaptor arbor. Each interchangeable stamp has a flat ground on one side. The set screws bear on these flats, thus insuring perfect radial alinement no matter what size bushing is used for the solid stamp.

PLASTICS CLAMP SUPPORTS

Unaffected by Atmospheric Conditions, Will Not Corrode or Sweat

FOR MOUNTING wires, cables, tubes, pipes and so on, newly designed plastics clamp supports have high impact and tensile strengths. The plastics is an excellent insulator, which insures against short circuits when used in electrical installations, and the edges of the clamps are rounded, eliminating the possibility of cutting wire or tubing. The tough yet flexible plastics can withstand temperature changes between — 78 and + 180 degrees, Fahrenheit, and, unaffected by atmospheric conditions, they will not sweat or corrode. Produced by Holub Industries, Inc., they are available in 16 stock sizes ranging from 1/8 to 1 1/4 inch, in 1/16 inch variations.

Available in 16 stock sizes

FIRE-RESISTANT PAINT

Decorative Surfacing Will Not Sustain a Flame

FIRE-RESISTANT paint developed for the Navy is now available for commercial and domestic use Ready-mixed and self-sealing, the paint is applied in the conventional manner, and one coat covers wallpaper, plaster, composition, concrete, wood and so forth. The dried paint has a fine-textured flat finish and can be easily washed Called Fire Stop by its manufacturer, Plicote, Inc., the paint reaches maximum fire resistance two weeks after it is applied. It is available in a wide range of colors

ALL-WELDED SOLENOID

Small, With Great Strength And High Efficiency

FOR USE where powerful pull is needed in a small space, such as in appliances, pinball machines, safety devices, trip mechanisms and vending machines, a new all-welded solenoid develops a maximum pull of 26 pounds in a half-inch stroke, operating on 110 volts, 60 cycles.

An L-shaped mounting bracket permits horizontal or vertical mounting of the solenoid, which is produced by the General Electric Company. Frame and bracket are welded together for long life. Frame laminations are of silicon

steel, making possible more pull per watt input, and high efficiency is achieved by welding these laminations together. Welding reduces eddy current losses, since the welds are outside the magnetic flux path.

The removable coil, sealed inside a plastic housing, is paper layer wound, heat treated to remove moisture and impregnated with a plastic. It is highly resistant to shock, splashing water and oil.

Plunger laminations of silicon steel are welded. A new type of pole shader, brazed into place, provides maximum quietness at a lower watt consumption.

TENSION METER

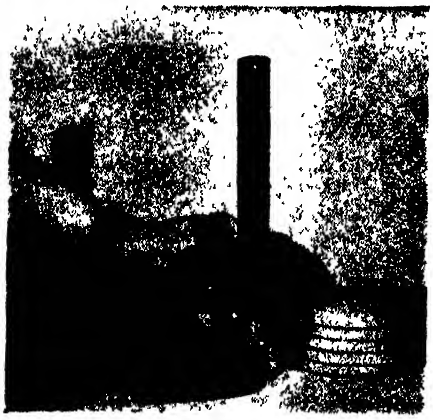
Check on Thread Strain Speeds Manufacturing Processes

STRAIN on threadlike materials can be measured quickly by a new tension meter, thereby preventing breaks and speeding manufacturing processes using such materials. The meter, developed by Dr. Erwin J. Saxl of the Saxl Instrument Company, gives a reading of thread tension on a dial. It may be used to measure the tension of threads in all types of textile machinery, such as those used in warping, quilling, throwing and spinning of all types of yarns. In non-textile production, it may be applied to the winding of ammeter coils, elastic rubber threads, cords for tires, wire for incandescent lamps and the uniform manufacture of helical grids in radio tubes.

VERNIER HEIGHT GAGE

Features Low Cost and Simple Operation

FOR GENERAL shop and production work and for model making, a new low-cost vernier height gage has a stainless steel scale measuring in hundredths of an inch from zero to six inches and in fractions by sixty-fourths. A metric scale is also available, as is a choice of cast iron or aluminum base. The slide, which has a hardened steel scriber, is easily adjusted by a large plastics knob. The accessories which may be obtained with this gage, manufactured by the Aim Instrument Corporation, includes a depth reading bar and indicator adapter, an adjustable go-no-go gage for production work, and a pencil lead holder which will be of especial interest to the pattern maker.



Height gage in use with lead holder

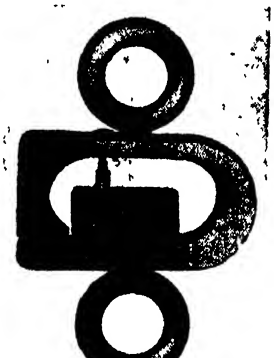
SAFETY SCALE

Weighs Accurately and Warns of Overload

WEIGHING loads up to 10,000 pounds, a versatile "monitor" flashes a caution signal, rings a bell, and cuts out the hoist motor on chain or cable hoist, and overhead cranes in case of overload.

Made of special alloy tool steel, this new device, called the Dyna-Switch, can be attached between overhead rail and hoist, or between hoist chain and hook in a few minutes. On cranes it is placed directly on the hook.

After a great many stress cycles in tests, it is claimed that the device always returns to true zero. It withstands accidental overloads far in excess of the limit called for by hoist or crane without affecting calibration.



Rings a bell, flashes a light or cuts off the motor when hoist is overloaded

The Dyna-Switch, product of W. C. Dillon and Company, is made in the basic model, with motor cut-off; visual model, with red caution lamp; and weight model, in seven types—from 0 to 100 pounds, to 0 to 10,000 pounds, with indicators showing 1 to 100 pound divisions.

The switch is 7⅞ inches from top to bottom of eye bolts and weighs 3¼ pounds. The switch is a Burgess Micro-Switch type.

MINIATURE RESISTORS

In Four Sizes, Feature Close Tolerance

FOR SMALL electronic equipment where space is at a premium, a new line of miniature resistors are said to be both dependable and accurate. Produced in four sizes ranging from 150,000 to 550,000 ohms, the units have a tolerance of 1 per cent, and closer tolerances can be furnished on special order. These Akra-Ohm Precision Resistors, as they are called by the producer, the Shallcross Manufacturing Company, are equipped with two-inch tinned copper leads, and the units are sufficiently light and small, that they can be suspended from their leads for mounting. Windings are non-inductive, and a special impregnation permitting operation under highly humid conditions, is available.

Resistors have tolerance of 1 per cent

PNEUMATIC RIVETER

Combines Hammer Action With Rotation

WITH interchangeable heads of four capacities, a pneumatic riveting machine which combines hammer action with rotation can be applied to assemly of parts made of metal, plastics, porcelain, fiber, wood and so on. The interchangeable heads of the machine, product of the Schlack Manufacturing Company, are available for rivet capacities to 3/32, 5/32, 1/4 and 5/16 inch base based on soft steel. It mounts a motor-driven spindle for peening tools to form round, oval or flat heads; to peen shafts, pins, studs; or to flare small tubes and connectors.

The spindle is carried in a spring-supported frame, sliding on a vertical column that is equipped with a foot pedal to bring the tool, called Pneu-Spin, down on the work. Above the spindle head is a pneumatic hammer

The pneumatic hammer is able to strike from 4000 to 6000 blows per minute with a quarter inch stroke to the rotating tool

that imparts 4000 to 6000 blows per minute with a 1/4 inch stroke to the rotating tool from a 75 to 80 pound air supply. Force and frequency are adjustable at the valve. Work is supported by an aluminum pressure pad attachment carrying a spring-backed pad. The pad foreruns the peening tool to hold work rigidly against rivet set or fixture. A positive stop assures uniform rivet heads and is adaptable to the assembly of moving parts. Vertical spindle movement is through 2 1/2 inches with vertical adjustment through 4 1/2 inches, and the throat measures 4 1/2 inches. The overall height is 65 inches, the anvil height 40 inches.

HANDY PAINT SPRAYER

Operates by Foot Pump, Needs No Cleaning After Job

Particularly well suited to small scale touch-up paint jobs, a portable paint spraying unit operates by means

Paint supplied in disposable containers

of a foot pump. The paint for the sprayer is supplied in disposable containers, so there need be no cleaning up after a job, or when changing colors. The unit, manufactured by Cesco Products, Inc., is supplied complete with spray gun, foot pump, six feet of air hose and an accumulator tank.

resists thermal shock better than ceramics; and has a specific gravity about a third that of tungsten carbide, and two thirds that of steel. Pieces of this composition have been heated to 2100 degrees F. for 48 hours without loss of strength. Neither does it change appreciably when heated to 1800 degrees F. and quenched in water. Air cooling from the same high temperature leaves no effect other than initial discoloration of the surface.

NEW CEMENTED CARBIDE

Hard Titanium Compound Resists Great Heat

A new cemented carbide composition, the same type of hard compound widely used in cutting tools and wear-resistant parts, has been developed which retains its strength and resistance to corrosion at high temperatures. The new composition, called Grade K138 by Kennametal, Inc., withstands temperatures that destroy conventional carbides and cast alloys; resists thermal shock better than ceramics; and has a specific gravity about a third that of tungsten carbide, and two thirds that of steel. Pieces of this composition have been heated to 2100 degrees F. for 48 hours without loss of strength. Neither does it change appreciably when heated to 1800 degrees F. and quenched in water. Air cooling from the same high temperature leaves no effect other than initial discoloration of the surface.

The new carbide's properties suggest many practical uses. Resistance to oxidation and hot gases, together with abrasion resistance due to high hardness, make it suitable for high temperature structures such as furnace parts and guides for hot rolled metal. Its light weight and strength are advantageous for rotating parts exposed to high temperatures. The new heat-resistant material consists essentially of titanium carbide with cobalt as the bonding element. The titanium carbide has heretofore been used only as a minor ingredient of cutting tool alloys.

HUMIDITY DETECTOR

Sensitive Element Is Film Changed By Moisture Content of Air

A new humidity detector utilizes a thin film which is unusually sensitive to changes in the moisture content of the air. Variations in moisture similarly alter the electrical resistance of the film, making possible direct meter readings of humidity. Such readings are of

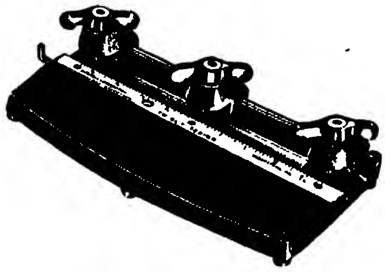
considerable importance in many manufacturing processes.

The detecting element, manufactured by the American Instrument Company responds to changes in humidity in less than a second. It will record variations in relative humidity of 0.1 per cent. Changes in barometric pressure do not affect its accuracy. In various applications, it may be used to indicate or record humidity, or to control processes influenced by humidity.

PAPER DRILL

Cuts Holes in Up to 200 Sheets Of Paper in One Operation

Having a capacity of 200 sheets (one half inch) per operation, a new hand operated paper drill is designed for



Multiple-hole paper drill

drilling holes in magazines, records, reports, loose-leaf sheets and so on. Manufactured by Mitchell Corporation, Twirlit drills are available in both single- and multiple-hole models.

TELEVISION RECORDING CAMERA

Motion Picture Is Made Directly From Monitoring Tube

Said to be the first of its kind, a new camera produces motion pictures directly from the face of the monitoring picture tube in a television broadcasting station. The camera which takes pictures at the rate of 24 frames a second, was developed by Eastman Kodak Company in coöperation with the National Broadcasting Company studio at station WNBT and the Allen B. DuMont studio at station WABD. Main uses of the new camera in television broadcasting will be:

1. To enable the recorded programs to be reused by the sponsor for institutional public relations and advertising.
2. To record transmitted shows for billing requirements.
3. To record all "live" programs that go out on the air. This use, for example, will be important for legal purposes.

Another possible major use, still in the experimental stage, is in a television "film network." The new camera photographs the monitor tube in the broadcasting studio. This tube shows everything that is transmitted and is used by the station to keep constant supervision of the program.

If a film network proves feasible,

The camera would photograph television programs by recording them as shown on the monitor tube. These film records of "live" programs could then be re-broadcast by stations in other cities. This would supplement the present limited and expensive television networks using coaxial cables and radio relays.

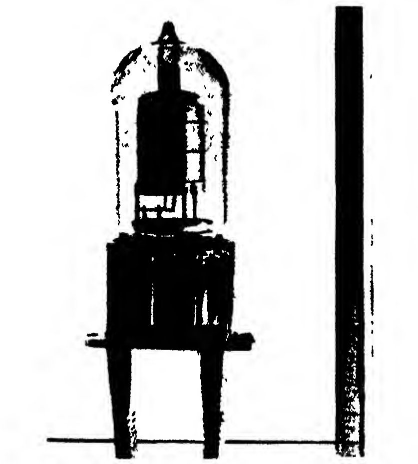
Basic camera design features of the camera include a 1200-foot film magazine that permits continuous recording of a half-hour program; separate, synchronous motor drives for the shutter and film-moving mechanisms, a coated f/1.6 lens of two-inch focal length.

The double-chamber magazine is a self-contained unit housing both the unexposed and the exposed film. It may be readily removed from the camera. Light-locks allow changing of loaded magazines in a lighted room.

HIGH-ALTITUDE TUBE

Air Forces Sponsor Development For Use In Guided Missiles

DESIGNED for service at altitudes higher than 60,000 feet, a new type of high-voltage vacuum tube has been developed under the sponsorship of the Air Material Command of the Army Air Forces. The principal application of the tube will be in the control circuits of guided missiles. The most important feature of the tube is a base made like a glass bottle stopper This construction excludes all air which, at high altitudes, can cause arcing at the terminals.



The tube base and socket construction eliminates flash-over at the terminals

The tube socket is the exact counterpart of the tube, with its angle of taper large enough to keep air from being trapped when the tube is plugged in. This design keeps the air exit open until the bottom of the tube reaches the bottom of the socket.

The socket is made of a bonded glass-mica composition which will not carbonize in an electrical breakdown. The original tube, manufactured by the Amperex Electronic Corporation, is a high vacuum, half wave rectifier rated at 14,000 volts peak inverse. Although rated only 14,000 volts peak, this tube-socket combination will handle voltages to 35,000 volts peak.

The new design is applicable to all types of high voltage vacuum tubes which may be subjected to similar high-altitude conditions. When used in areas which are strongly radioactive, tubes of this type will not break down externally due to ionizing action.

HIGH-SPEED RELAY

Features an Operating Time of One-Millionth Second

ASSEMBLED in a standard metal radio tube container, a new high-speed D.C. relay is said to have an operating time of one millionth of a second. The unit, called a Millisec Relay, is made by Stevens-Arnold, Inc., in one size, single-pole double-throw, for use with resistive loads, and is equipped with a shielded coil for those applications where shielding is desired between the coil and contacts. The contacts are rated at 110 volts, D.C., one-half ampere.

PHENOLIC TUBULAR CAPACITORS

Molded Plastics Condensers Operate In High Heat, Moisture, Shock

MOLDED phenolic tubular capacitors feature rugged construction and high heat- and moisture-resistance. They are conservatively rated for operations under temperatures ranging from —40 degrees to +85 degrees C, and generally speaking, they are slightly smaller than paper condensers of comparable ratings. The phenolic-sealed construction of these capacitors, manufactured by the Sprague Electric Company, makes possible dependable operation under severe conditions of heat, moisture or mechanical stress. They are available in all popular capacities in 200, 400, 600, 1000 and 1600 volt types.

The Editors Recommend

Best Sellers in Science and Technology

GUIDE TO THE LITERATURE OF MATHEMATICS AND PHYSICS — *By Nathan Greer Parke III.* A guide for self-directed education in both mathematics and physics. The major part is a classified list of books in each sub-class of both subjects and in related engineering subjects. **$5.10**

ANCIENT PLANTS AND THE WORLD THEY LIVED IN — *By Henry N. Andrews, Jr.* The science of the past evolution of plants told for readers with a serious interest in pure science. **$4.60**

HANDBOOK OF CHEMISTRY — *By N. A. Lange.* Sixth edition of a well known handbook of chemical information, reset and greatly corrected. A useful and convenient volume. **$7.15**

HIGH FREQUENCY INDUCTION HEATING — *By Frank W. Curtis.* Answers many questions concerning induction heating and its utility in industrial processes. Thoroughly practical in scope. **$3.10**

MUSICAL ACOUSTICS — *By Charles Culver.* Textbook for college students majoring in music, and essentially physics throughout. Covers all important phases of acoustics of music. **$3.10**

PLASTICS — *By J. H. DuBois.* Third edition, again revised and enlarged, with two four-color plates This is an important book on the whole general subject of plastics, plus much brand new material on synthetic rubber, manufacturing processes, and plastics moldings. **$5.10**

NORTON'S STAR ATLAS AND TELESCOPIC HANDBOOK — *By Norton and Inglis.* Tenth edition of a standard work, with main charts redrawn for epoch of 1950. Standby for amateurs past the cradle roll. **$5.35**

THE MEANING OF RELATIVITY — *By Albert Einstein.* Second edition with added chapter describing advances since publication of first edition some 25 years ago. Requires knowledge of advanced mathematics and physics, not a popular exposition. **$2.10**

THE SCIENTISTS SPEAK — *Edited by Warren Weaver.* A review of recent advances in all of the sciences and a wide ranging discussion of the meaning of science in the modern world This book brings together the 79 "science talks" by 81 distinguished scientists which were broadcast at the intermission of the New York Philharmonic Symphony Sunday afternoon concerts in the 1945 46 and 1946 47 seasons. **$3.85**

RADIANT HEATING — *By T. Napier Adlam.* Complete information for engineers, architects, and contractors on design, installation, and control of hot water, steam, warm air, and electric radiant heating systems. **$6.10**

SLIDE RULE SIMPLIFIED — *By C. O. Harris.* How to use a slide rule, without any of the mystification that often surrounds this important tool of the engineer. Excellent illustrations make everything clear. $4.10 including a slide rule; for book alone **$2.85**

MACHINERY'S HANDBOOK — *13th Edition.* "Bible of the mechanical industry." 1911 pages of latest standards, data, and information required daily in shop and drafting room. **$6.10**

PROCEDURES IN EXPERIMENTAL PHYSICS — *By John Strong, Ph.D.* A wealth of useful data of a practical kind for the constructor, experimenter, and skilled craftsman. **$7.45**

EXPERIMENTAL SPECTROSCOPY — *By Ralph A. Sawyer.* Covers theory and types of spectroscopes and spectographs, mounting and use of gratings, determination of wavelengths, infra-red spectroscopy, spectrochemical analysis, and so on. Somewhat elementary, but requires knowledge of physics and some physical optics. **$5.10**

THE EINSTEIN THEORY OF RELATIVITY — *By L. R. and H. G. Lieber.* An intermediate book from which engineers and the like can get close to an understanding of relativity. Partly in language but largely in mathematics of college grade, mainly calculus. **$3.10**

HEAT PUMPS — *By Sporn, Ambrose, and Baumeister.* Presents the basic facts on the design, operation, installation, and maintenance of heat pumps for either heating or cooling in domestic and industrial applications. **$3.85**

PRINCIPLES OF PHYSICS, VOL. III—OPTICS — *By Francis Weston Sears.* One of the most modern works on physical optics available today At college level, it covers the subject with emphasis on physical principles rather than practical applications. **$5.10**

IF YOU MUST GAMBLE—*By Maurice Lenihan* Statistical safety, as practiced by insurance companies, applied to bridge, dice, roulette, horses and so on. No guarantee of successful "systems," but sound advice lightly handled **$2.10**

EXPERIMENTAL PLASTICS AND SYNTHETIC RESINS — *By G. F. D'Alelio.* Explicit directions for making most of the well-known plastics and resins, using a minimum of laboratory equipment Many of the processes can be translated directly into industrial applications. **$3.10**

FUNDAMENTALS OF OPTICAL ENGINEERING — *By Donald H. Jacobs.* This work starts out at the very beginning, is mainly non mathematical, and is probably the best suited of all existing books as an introduction to optical design. Author is a physicist at Bureau of Standards. **$5.60**

THE HOME FREEZER HANDBOOK—*By Gerald J. Stout.* Detailed instructions for building and operating home freezers, large and small, that are low in first cost and economical to run. Section on preparation of foods for freezing. **$4.10**

INDUCTION HEATING — *By Osborn, Brace, Johnson, Cable, and Eagan.* Principles and theory, practical applications of motor-generator and high frequency induction heating, circuits and frequency generation, and comparisons of heat-treating methods. **$3.10**

AN OIL BURNER HANDBOOK—*By L. J. Whelan.* How oil burners work, how to get the greatest efficiency from them, how to conserve fuel, and what to do about troubles, are all told here in simple, understandable language—for home owners or technicians. **$2.50**

(The above prices are postpaid in the United States. Add, on foreign orders, 25¢ for postage on each book, except as noted. All prices subject to change without notice. Books listed are offered for retail sale only, not to the trade.)

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CURRENT BULLETIN BRIEFS

Conducted by K. M. CANAVAN

(The Editor will appreciate it if you will mention Scientific American when writing for any of the publications listed below)

Lithcote. In eight pages this catalog describes and illustrates this protective coating and lining process for steel and other metals, which is applicable to many types of storage and transportation equipment. A wide range of uses is described, and the results of laboratory tests are given. *Lithgow Corporation, 333 West 40th Place, Chicago 9, Illinois.—Gratis.*

Seam Welders. In eight pages this bulletin presents information on standard and special seam welders which are available in three sizes—light, medium and heavy duty. Each size is also available in three types—circular, longitudinal and universal. Typical applications are shown. Request Bulletin 803. *Progressive Welder Company, 3050 East Outer Drive, Detroit 12, Michigan.—Gratis.*

Combustion Systems and Burners is a 12-page booklet outlining the basic principles of gas-fired combustion systems. The function of four types of burners—atmospheric, immersion, low pressure and high pressure—are presented, and sectional drawings and charts of types of burner-equipment illustrate the text. *Surface Combustion Corporation, Technical News Bureau, Toledo 1, Ohio.—Gratis.*

Precision Ball Bearings is a 20-page catalog which lists and describes the various types of ball bearings, giving milimeter equivalents, bearing specifications and bearing equivalents as well as a comprehensive chart explaining the standard AFBMA bearing numbering code A pictorial section shows precision ball bearing methods. Request Catalog 2001. *Jack and Heintz Precision Industries, Inc., Cleveland 1, Ohio.—Gratis.*

Pines Benders. Outlining various innovations in bending machines, this 18-page catalog illustrates machines which are designed to speed up the production of bends in pipe, bars, tubes and extruded shapes. Typical applications of these machines as used in the metal furniture, refrigeration, processing equipment, bicycle, aircraft and automotive industries are shown. *Pines Engineering Company, 601 Walnut Street, Aurora, Illinois.—Gratis.*

The Architecture Of Broadcasting Transmitter Buildings is Issue No 9 of the Western Electric *Oscillator.* The information contained in this 68-page booklet has been compiled with the aid of network engineering executives and leading architects. It covers such subjects as site selection, layout of buildings, construction methods, and de-

signs for modern transmitter buildings. Many typical buildings and installations are shown. *Western Electric Company, 195 Broadway, New York 7, New York.* --*Gratis.*

OUTLINE OF LECTURES ON ADVANCED RADIO SERVICING. This 32-page booklet contains many helpful facts taken from a manual of 30 lectures on radio servicing. Included are pointers on location of store, advertising, how to obtain business, rates and charges, as well as the necessary equipment for locating faults and so on. *Supreme Publications, Nine South Kedzie Avenue, Chicago 12, Illinois.—10 cents*

CONTINUOUS SOLVENT EXTRACTION PROCESS. Providing detailed information on the handling of soybeans, cottonseed, flaxseed, peanuts, corn germ and castor beans, this 20-page bulletin describes and illustrates the equipment available for the extraction process and analyzes its economies. Request Bulletin 13B6757. *Allis-Chalmers Manufacturing Company, Milwaukee 1, Wisconsin.—Gratis.*

THE INSIDE STORY. In 44 pages this booklet, in interesting cartoon style, tells the story of how the Yale compact door closer operates. *The Yale and Towne Manufacturing Company, Public Relations Department, Chrysler Building, New York 17, New York.—Gratis.*

HIGH INTENSITY RUNWAY LIGHTING. In 12 pages this bulletin contains descriptions of the use, installation and ratings of this type of equipment which is being distributed by the General Electric Company's Apparatus Division. Request Bulletin GEA 4931. *American Gas Accumulator Company, 1027 Newark Avenue, Elizabeth 3, New Jersey —Gratis.*

ANNEALING IN STANDARD RATED FURNACES. Defining various annealing and related processes for both ferrous and nonferrous metals, this four-page bulletin also describes both direct fired and prepared atmosphere furnaces—discussing the advantages of each. Request Bulletin SC-135. *Surface Combustion Corporation, Technical News Bureau, Toledo 1, Ohio.—Gratis.*

X-RAY DIFFRACTION CAMERA FOR MICROTECHNIQUES is a four-page reprint which outlines the construction and application of this camera which is especially adapted to fiber analysis. Sample diffraction patterns are shown for unstretched and stretched polyethylene. *North American Philips Company, Inc., 100 East 42nd Street, New York 17, New York.—Gratis.*

WATCHMAN—WHAT WOULD YOU DO? This 12-page booklet, illustrated with instructive cartoons, is useful as an aid to plant managements in training watchmen in the proper procedure when fire is discovered. Stressing eight important fundamentals, it includes the operation of extinguishers, calling the fire department, checking sprinkler valves and starting fire pumps. *Associated Factory Mutual Fire Insurance Companies, 184 High Street, Boston 10, Massachusetts.—Gratis.*

Books

THE BOOK DEPARTMENT of Scientific American is conducted, with the co-operation of the Editors, to make available for you a comprehensive book service. Each month the Editors select and review in these columns new books in a wide range of scientific and technical fields. In addition, they are ready at all times to advise you regarding the best available books on any subject. You are invited to use this service freely. Tell our Book Department what kind of books you want and you will be furnished with the names of available books, including prices. When inquiring about books, please be specific; remember that we can be of the greatest help only when you tell us just what you are looking for. Books listed in these columns may be ordered from our Book Department. Add 25 cents per book for mailing outside U. S. All remittances are to be made in U. S funds Prices given are subject to change without notice.

APPLIED CHEMISTRY

By Sherman R. Wilson and Mary R. Mullins

One of the by-products of the intensive development of chemistry during the war is the necessity it has created for revision and amplification of text books. Students are particularly avid to learn something about all the late developments that have received major attention in the news following the lifting of wartime censorship. This new edition of the high school chemistry text of Wilson and Mullins sets out to accomplish just that. Sometimes it finds the going a little tough in its efforts to explain the more abstruse developments to an audience of beginners in chemistry (to whom the book is definitely directed) but on the whole it does an effective job. (714 pages, 5½ by 8½ inches, copiously illustrated.)—$2 50 postpaid.—*D.H.K*

FLIGHT ENGINEERS MANUAL

By Charles A. Zweng

The duties of a flight engineer on the airways are as important as those of the pilot, and require perhaps greater knowledge. The book, written as a help to the passing of the Flight Engineer's Certificate examination is clear, accurate, comprehensive, up to date. It contains a wealth of information concisely presented on aircraft and engine operation with special attention to the Constellation, the DC-4 and the Boeing Stratoliner. (416 pages, 10½ by 6¾ inches, illustrated.)—$4.10 postpaid.—*A K*

INVENTIONS AND THEIR MANAGEMENT

By Alf K. Berle, S.B., and L. Sprague De Camp, M.S.

Millions of dollars of lost profits, thousands of hours of frustration, hundreds of law suits, could be saved if inventors would take the time and trouble to get clear ideas about the complexities of protecting, marketing and developing their inventions. This book does not tell the whole story; only a first class patent lawyer can do that for the inventor. But in the hands of any individual inventor or in the engineering library of any large manufacturing company this book can give concise answers to some of the most perplexing problems of the inventor. (742 pages, 5½ by 8½ inches, about 100 illustrations.)—$6.10 postpaid.—*E.L.C.*

NEW WEAPONS FOR AIR WARFARE

Edited by Joseph C. Boyce

Another in the series, "Science in World War II," this volume deals specifically with the development and production of (1) Radar fire control equipment, (2) Proximity fuses for rotating projectiles; (3) Proximity fuses for rockets, bombs and mortars; and (4) Guided missiles. The book, edited by a former special assistant to the chairman of the National Defense Research Committee, is written in easily understood not-too-technical language, making it a work of very decided interest to the layman (292 pages, 5½ by 8½ inches, illustrated) — $4 10 postpaid — *N H U*

THE REACH OF THE MIND

By J. B. Rhine

Readers wishing a summarizing account of the status of Professor Rhine's 17 years of research on extra-sensory perception—telepathy and clairvoyance (both free from time and space limitations), precognition and psychokinesis, the action of the mind on objects—will find it rounded up in this new book, though the frequent use of symbols like PK, DT, QD, and psi is wearisome. It surprises everyone to discover how much evidence there is for extra-sensory perception. Some scientists have become convinced, physicists are found the most objective, and many psychologists who are personally convinced are noncommittal due to reasons of expediency. Despite the convincing evidence as Rhine presents it (with a little impatience), science's lack of a stampede to full acceptance has the same stabilizing effect that an opposition bench has on a government party in

power. Most interesting parts of the book are the later chapters discussing in detail the consequences, philosophical, ethical and everyday-practical (everybody's mind an open book, but you've still a chance to reform) that would follow if we could get voluntary control of what actually is a feeble, undependable, seldom useful agency. People said we'd never get control of atomic energy. (234 pages, 5½ by 8¼ inches, 17 illustrations.)—$3.60 postpaid.—*A.G.I.*

THEY TAMED THE SKY

By Douglas J. Ingells

THIS IS an accurate, straightforward, well-written account of the research and engineering that created our military aircraft, its armament, engines and equipment. The story of our fighting pilots is known to everybody. Here is the story of Wright Field, of the patient engineers and test pilots who paved the way for giving the combat pilots their tools. The book is the result of careful research, and it does not exaggerate. Perhaps it is all the more dramatic on that account when it tells what happens to a man deprived of oxygen in the stratosphere, of the tremendous hazards of the test pilot, of the wonders of jet propulsion, of what can be done in huge wind tunnels, of the marvels of radar, of the way jet planes and rockets shrink space. (268 pages, 5½ by 8 inches, illustrated.)—$3.60 postpaid.—*A.K*

COMMERCIAL FERTILIZERS

By Gilbeart H. Collings

THE FOURTH edition of this valuable text book brings the subject of fertilizers and related matters quite up to date. Copious illustrations, including a number in color, add greatly to the value of this authoritative work, both to the student and to others interested in the production and application of fertilizers. An extensive bibliography and an excellent index complete an excellent book. (522 pages, 6 by 9 inches, illustrated.)—$4.60 postpaid —*D.H.K.*

PRIMER FOR HOME BUILDERS

Edited by Allan Carpenter and Norman Guess, and the Editors of Popular Mechanics

THIS tome should reduce somewhat the probability of the inexperienced home-seeker suffering a complete catastrophe at the hands of the builder or real estate salesman. Pointing out the many pitfalls threatening home builders and buyers, this highly readable book covers, among many others, such vital details as how to plan the house; what materials should go into the house; what the architect and contractor do; and, in the case of an older house, what danger signals to heed if one is to avoid ending up with a hopeless termite trap. Of special interest is the section dealing with the more important legal aspects of building or buying. Here, these usually confusing issues are reduced to simple English, with their full significance dragged out into the open. A "must" for the novice, this book can teach even the experienced house-hunter a thing or two. (171 pages, 8½ by 5½ inches, illustrated.)—$2.60 postpaid —*N H.U.*

Because of increased production costs of books, publishers' retail prices today are subject to constant change. It may be necessary, therefore, for our Book Department to advise book purchasers of increased costs, even when orders sent are based on current quotations.

The Editor

AN INTRODUCTION TO METALLURGY

By Joseph Newton
Second Edition

AN EXTRA-COMMENDABLE aspect of this second edition of a commendable textbook on metallurgy is its inclusion of references (although necessarily too brief) to nuclear fission and its products. It also contains an expanded discussion of pyrometallurgy and a new section on powder metallurgy. It might well have also added a section to identify and date personalities mentioned in the text (*e.g.*, Bain, Bessemer, Gibbs, Thum) and thus give some little historical perspective to a technology which Professor Newton (of the University of Idaho) notes "still makes use of some rule-of-thumb methods, and still finds it necessary to employ artisans to do work which cannot be learned from scientific textbooks." (645 pages, 6¼ by 9¼ inches, illustrations.)—$5 60 postpaid.—*M W*

THE WORKS OF THE MIND

Edited by R. B. Heywood

TWELVE lectures, by an artist, sculptor, architect, musician, statesman, legislator, administrator, scientist, mathematician, historian, philosopher, who discuss the creative processes by which they work—at least some do. Others wander more or less hither and yon (246 pages, 5¾ by 8½ inches, unillustrated)—$4 10 postpaid —*A.G.I.*

SMALL WONDER
The Story of Colloids

By Gessner G. Hawley

THIS book is written in such a clear and simple style that at the start it seems intended for a popular audience. But as the reader progresses he finds that it is an intensely serious work, sufficient for the needs of all who must deal with colloids in any other respect than to design equipment, or to make scientific studies. Thus we have a book which is clear enough to be understood by any high school or college student, but is deep enough to meet the needs of public works officials, foods company executives, purchasing agents and others who must deal responsibly with

colloidal equipments and processes although rarely understanding them. The book would be excellent as a text for teaching. In the modern movement to make more science clear to more people this book deserves an important place. (230 pages, 8¾ by 6 inches, illustrations, charts, and drawings.)—$3.60 postpaid.—*E.L.C.*

BASIC ELECTRONIC ELECTRICITY

By James R. Cameron

From the fundamentals of electric charges through the structure of matter and a discussion of voltage and current, this solid yet somewhat simplified text carries the reader along to vacuum tubes and their applications in various fields. The text is remarkably clear in its exposition, and it is to be regretted that the numerous drawings are very poorly executed. (320 pages, 5 by 8 inches, about 200 illustrations.)—$5.10 postpaid.—*A.P.P.*

THE CHEMICAL COMPOSITION OF FOODS

By R. A. McCance and E. M. Widdowson

Second American edition of an English work on the composition of foods, prepared primarily for the guidance of the dietitian, the important content of this book is given in tables which show composition in grams or milligrams per hundred grams or cubic centimeters, or in grams or milligrams per ounce, of a great variety of common foods. Recipes are given for a number of prepared foods whose compositions are included in the tables. The book is obviously English both in the selection and naming of the foods included, but neither this nor its English peculiarities of spelling and choice of words will prevent the earnest seeker for information from finding it. Rather, these oddities natural to its English origin will merely annoy American users of the book. (156 pages, 5½ by 8 inches.)—$3.85 postpaid.—*D.H.K.*

MUSIC IN RELATION TO EMPLOYEE ATTITUDES, PIECEWORK PRODUCTION, AND INDUSTRIAL ACCIDENTS

By Henry Clay Smith

This paper-bound monography is the result of a 12-week study of 1000 factory employees. Dr. Smith (of Hamilton College) succinctly concludes: "Music during working hours will generally improve production where repetetive work is common. Properly administered in such situations, it not only will increase production but will also provide widespread employee satisfaction. . . . Although music, on the average, had no influence on the accident rate, the relation of music to accidents was not entirely clear in the present study." (59 pages, paper covers, 6 by 9 inches, tables and charts.)—$1.85 postpaid.—*M.W.*

BUG BITES HARD

And This is What Resulted

"This," writes an Omaha amateur telescope maker, "is what happens when the bug gets out of the 'A.T.M.' book and bites you really hard."

The top one is five inches in diameter—small and easily portable.

The next one is six inches in diameter—customary size for the beginner's first telescope, magnifying 100 diameters. The lower two are ten inches in diameter but differ in length for special uses. These can be carried out of doors

Tubes of four telescopes

and attached to a fixed mounting and pointed anywhere in the sky.

Why did this man make four telescopes? For the same reason that a fisherman may own nine rods and eleven reels.

Below are three telescopes made by a physician in Haven, Minnesota. First

Many make three to six

he made the center one, six inches diameter. Next the one at the right: same diameter but shorter—better for faint stars and nebulae. Third he built the nearer one, 9¼ inches in diameter, magnifying 200 diameters.

Telescoptics

A Monthly Department for the Amateur Telescope Maker

Conducted by ALBERT G. INGALLS

Editor of the Scientific American Books "Amateur Telescope Making" and "Amateur Telescope Making—Advanced"

Two of Porter's sketches, Figures 1 and 2, "were made," he writes, in the optical shop in Pasadena while the 40" glass plug, weighing 450 pounds, was being removed from the 200" mirror. It was a delicate operation, as the plug was cemented into the large mirror with plaster of Paris. The men are shown digging out the plaster. Figure 2 shows the face side."

Time out to gasp. Is that workman a housewrecker recklessly wielding a crowbar on the finished, figured, completed mirror? So Porter was asked and answered, "The 'crowbar' was a rod of steel only about 1/4" in diameter, and the technique was simply digging out the plaster little by little, the clearance between the mirror and plug being about 3/8". The last segment was undug at the top, so that when this finally broke away the plug just dropped onto a bed of powdered plaster underneath."

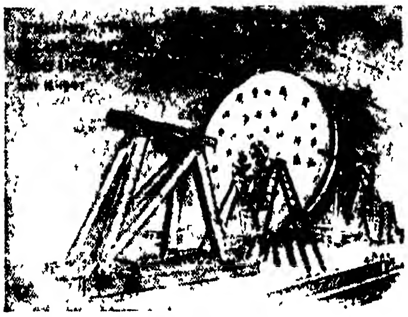

Figure 1: Hole enters plug

"In the first sketch," Porter continues, "the mirror is shown as it hung from a strap from the 50-ton crane above. At the left is a massive supporting frame for a heavy horizontal timber with its end turned cylindrical (10" diameter) to fit a corresponding hole in the rear of the glass plug. When the glass plug was freed the crane advanced the mirror until the wooden plug entered the hole. Then the mirror was lowered slightly until the plug was loose and free, and was moved away from the plug, leaving it resting on the timber's end.

"It is interesting to remember how the glass plug was inserted, years ago It was rested on a cake of ice and, as the ice melted, the glass settled slowly, safely, into the 40" hole."

Since two pictures take the place of 20,000 words few words are needed to describe the clean, workmanlike brass-bronze telescope eyepiece focus control shown in Figures 3 and 4, designed and made by Philetus Allen, 1 John Street, Glens Falls, New York.

1 is the eyepiece.
2 is its standard 1 1/4" tubing
3 is the adapter tubing.
4 is the housing
5 is the hand control.
6 is its spindle.
7 is the worm.
8 is the worm rack.
9 is an adapting plate to fit tube
10 is the tube.
11 is a washer fitted inside tube
12 is a ring nut.
13 is a band.
14 represents face of worm rack
15 represents a section of the bottom, the keyway, and rack.

Your scribe has manipulated this focus control, which works as smoothly as a turtle's neck. Allen adds: "The worm rack, 8, was made by threading the inside of a length of brass tubing, 12 threads per inch, and then cutting a 1/4" section from this and soldering it to the adapter tube. The worm is of polished steel. Everything can be made on a lathe except the keyway and slot for the worm, which are shaper jobs"

Precisely in which details British and American standard astronomical eyepiece shells differ having long been something of a mystery, H. E. Dall, 166 Stockingstone Road, Luton, England, a co-author of "A.T.M.A.," was invited to contribute a note and kindly sent Figure 5. "This," he writes, "is a typical medium-power eyepiece of British standard thread type as used most commonly here. Advantages of the screwed mounting are easier to remove or insert without shaking the telescope; doesn't get stiff with lack of grease; and better for attaching cameras, spectroscopes and Barlow lenses.

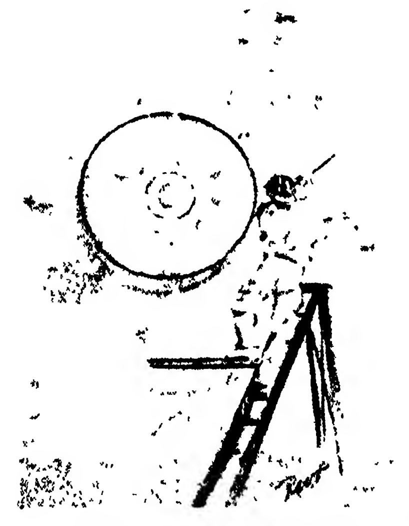

Figure 2: Mining out plaster

Generally, however, he comments, "the British product has too long a thread. Whenever I make them I try to confine the thread to one complete turn only. This is adequate for such a coarse pitch screw and is very quick to remove or attach.

"In my drawing," Dall continues, "a Huygenian eyepiece is shown, this being by far the most common astro eyepiece used in this country. It seems that the Ramsden type is more favored by Americans. The Huygenian gives no color fringes outfield, as does the Ramsden Dust on the field lens is not visible, especially to near-sighted folk. The eye clearance is greater. The somewhat higher spherical aberration is not troublesome until applied to short focus

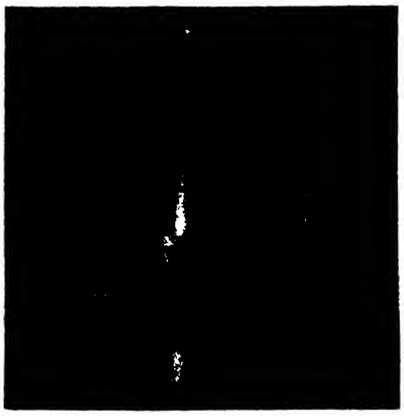

Figure 3, Allen focus control

mirrors, *f*/7 or shorter The advanced amateur will prefer the orthoscopic type to either, though for *f*/15 refractors there is no gain except greater eye clearance."

THOUGH the winter winds of the 9272-foot Pic du Midi in the central French Pyrenees violently shiver its outer shell, or carapace, (Figure 6), the telescope just within will remain always in a dead calm. This telescope at the famous French observatory is to be a 59", *f*/5 Newtonian-Cassegrainian. It is described in *L'Astronomie* (Paris) and will be something to watch. A translation:

"The principal original feature of the 150-centimeter reflector will be the fact that it is not to be sheltered in a dome. For this there are two reasons," says Director Baillaud. "The main one, the one that decided us, is that the air movements that exist in a dome in the neighborhood of the dome slot are an important cause of image troubles. The second in practical order is that we have not found a place on the top of the peak to build a big enough dome to house our reflector. The instrument will not be in the open air, even then; it will be sheltered by a sheath, a carapace, which will conform to all its outlines and follow along in all its movements without touching any part. This carapace will absorb the force of the winds. The axes round which the carapace will turn will be concentric with the axes which turn the telescope. The two polar axes will rest on piers so independent of each other that the

transmitted to the telescope by the earth.

"This altogether new design, which will seem very bold considering the severe climatic conditions on the Pic du Midi, was conceived in the course

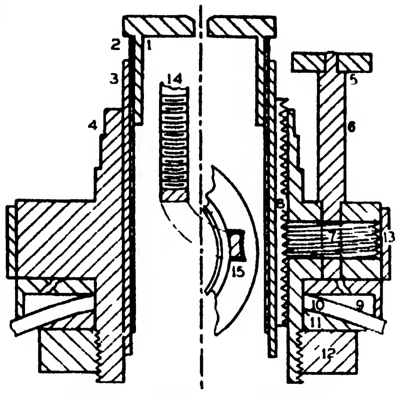

Figure 4: Focus control detail

of conservations between Monsieurs Lyot, Carmichel, Gentile, and myself," Dr. Baillaud continues. "The fact is, we believe that it will involve no complications and that it will not cost more than a dome. To us it seems to be the coming solution for reflectors larger than about 60" in diameter."

The men named as behind this daring design, a moving carapace unlike the fixed one which surrounds the tower telescope on Mt. Wilson, are the ablest practical optical scientists in France Dr. Couder is astronomer at the Observatory of Paris and, with Dr. André Danjon, is co-author of the book "Lunettes et Télescopes ("Reflectors and Refractors") a sort of advanced Bell which should be translated into English. Dr. Lyot is famous for his inven-

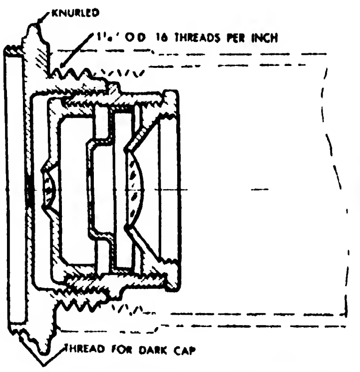

Figure 5: British eyepiece mount

tion, design, construction and use of the Lyot coronagraph by which solar eclipses can be made artificially at any time.

The three-meter shell or carapace enclosing the telescope will contain a little inner coop where the astronomers can observe at the Cassegrainian focus and another coop for the Newtonian focus, also ladders, the finder and a 19½" refracting telescope. Access to these coops will be by trap doors. The

coops will be air-controlled to a comfortable temperature but the air in the interior of the tube and in contact with the mirror will be held artificially at an even lower temperature than that of the air outside, in order to produce a stratification of the air which should tend to diminish its circulation within.

One other new feature of the Pic du Midi telescope is to seal the tube at the skyward end with a plane-parallel glass window to break up air currents. A somewhat similar proposal, though with a different object, has reached this magazine from S. L Walkden, father of the Richest-field telescope, London "I have speculated on trying the following. For a 6" Newtonian prepare a thin, say 3/16", plano-plano plate of finest low-dispersion optical glass and surface workmanship and place this in the main tube an inch or two farther out than the flat. Attach the diagonal to this and it becomes a supporting plate having no spider diffraction Film-coat the two surfaces of the glass to minimize light losses"

Multiplying the number of telescope makers by the number of mirrors made by each, and again by the coefficient of human carelessness Kc, we find that x plumbers have been called to y homes to clean abrasive gunk from z

Figure 6: Its skin doesn't touch

drain traps; while n carloads of only half-used Carbo have been wasted. Some thrifty mirror makers keep a deep pail under their washing spigot at all times and all grit from whatever source ultimately reaches its bottom and stays there unless the water is unnecessarily stirred up

After a few mirrors have been made this catch-all, now half full of gunk, is taken to a flowing brook and stirred until the milk (glass fragments) and finder grit have floated downstream. A surprising amount of clean coarse Carbo will be found in the bottom—enough to hog out the next mirror.

To re-grade this mixture probably would not pay. Moreover, this would require more equipment and skill than may at first seem called for. At least, the manufacturers of abrasive grains have long sought ideal ways to grade their product but found only approximations

ON THE COVER: Oxygen is directed through a jet device (at left of opening) at the molten bath in an open hearth furnace. Uses of oxygen in steel making are discussed in the story beginning on page 53.

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50 Years Ago in . . .

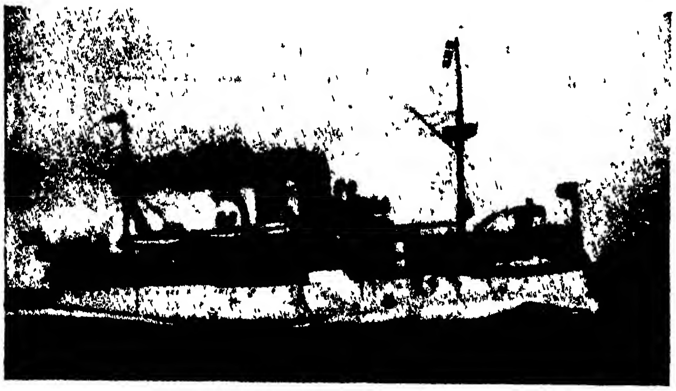
(Condensed from Issues of February, 1898)

LIQUID AIR — The economical liquefaction of air in large quantities has been recently accomplished by Mr. Charles E. Tripler, of New York, after several years of experimental work. Two and a half gallons of the liquid were recently sent from his laboratory to Prof. Barker, of the University of Pennsylvania, and its properties were exhibited in an extremely interesting series of experiments during a lecture delivered by Prof. Barker to his class and a company of invited guests. This was the first public exhibition of the kind in the United States.

VENUS — M. Flammarion, the astronomer, has been discussing the hypothesis of Schiaparelli, recently supported by Mr. Lowell and other observers, to the effect that the planet Venus, by rotating round her axis in the same period as she revolves round the sun, always presents the same face to the sun, as the moon does to the earth for the like reason. Flammarion thinks that the marks on the surface watched by Schiaparelli are effects of atmosphere and sunlight, and not on the body of the planet. He points out that the deep atmosphere of Venus probably absorbs so much of the light from its surface that we are unable to see the latter.

PARIS FORTIFICATIONS — After more than twenty years of discussion, the French Government is submitting to Parliament a scheme for the demolition of the fortifications of Paris from the Seine to the Porte de Flandres, a stretch of about eight miles It is expected that the Chamber will ratify the proposal, which will be of great service to Paris, in removing a boundary which stands in the way of free extension of the city, while it is no longer of value as a fortification, and, in fact, counted for nothing in the defense of Paris in 1871.

SINKING OF THE MAINE — The great calamity which has befallen the nation in the loss of one of its finest ships, with over two hundred and fifty of its brave and ever popular blue jackets, has brought mingled feelings to the hearts of the American people, feelings in which bewilderment and deep sorrow predominate. The perplexity and anguish which such marine disasters produce are here intensified by the extraordinary coincidences of time and place which render



the loss of the "Maine" suspicious and grimly suggestive. In view of the strained relations existing between the Spanish government and our own, the American people were fully justified in their first exclamation of "Treachery!" when they learned that their warship had been blown up at the dead of night in a Spanish harbor.

CORAL — Prof Alexander Agassiz has spent several months in the South Sea, mainly devoting his time to the study of coral animals. Both Darwin and Dana held that coral is made, sinks and is replenished on the surface. This they taught continued indefinitely, and this process was called the theory of subsidence. Prof. Agassiz now believes that coral is a comparatively thin crust formed upon a mountain that has been submerged or upon a volcanic pile, and in nearly every case where the borings have been made the coral has been found to be shallow.

CATHODE RAYS — Prof Lenard, of Heidelberg, who first discovered cathode rays, has received from the French Academy of Sciences its prize of 10,000 francs.

100 Years Ago in . . .

(Condensed from Issues of February, 1848)

POLAR COAL — In his lecture on the Sun, Prof. Nichol alluded to the fact that fields of coal have been discovered in the polar regions of our earth, plainly indicating that that portion of our planet was once lighted and warmed by an agent more powerful than any which now reaches it, and which was capable of sustaining vegetation of a tropical character.

BOILER EXPLOSIONS — Never within our recollection has there been a period marked with so many lamentable steamboat disasters in our country as the past four months First we heard of the conflagration of the Phoenix on her passage up the Lakes on the 21st of last November, with the loss of 101 lives. The steamer A. N. Johnson, on her first trip last month from Cincinnati to Wheeling, blew up with a tremendous explosion, and God only knows how many perished. One account in the Cincinnati papers stated that "more than one hundred lives were lost," probably nearly two hundred. The Cincinnati Commercial Advertiser stated from a description of one who witnessed the disaster, that there were some saved, who in the delirium of their sufferings begged to be shot, and others called for axes to end their sufferings.

COMPRESSIBILITY — That quality by which a body allows its volume to be diminished, without diminishing its mass, is called compressibility. This effect is produced by bringing the particles which constitute said body closer together, increasing thereby the density and diminishing the pores. All known bodies are capable of having their dimensions reduced by pressure, or percussion, without diminishing their mass. This is a strong proof that all bodies are composed of atoms, the spaces between which may be diminished.

MADE IN ENGLAND — "I have been informed," says a missionary to India, "that some merchants in Birmingham have made a good speculation lately, in manufacturing idols of brass for the India market, for which they have found a ready sale. It was mentioned to me as a fact last year, that two missionaries were embarking for Calcutta on board the same ship which carried several chests filled with idols."

MONSTER ENGINES — The British Great Western Company Railroad, a short time since, placed upon their road, a monster engine, called the "Iron Duke," of thirty-six tons weight. It was found to work so well, that the Company have ordered sixteen more locomotives of about the same gigantic dimensions—a portion of them to be furnished with eight-foot driving wheel.

AN ANNOUNCEMENT TO OUR READERS

It has already been announced on this page that the Scientific American is presently to become a new magazine, under a new ownership and a new board of editors. While the new Scientific American is in preparation, however, the magazine will continue regular publication without major change. The first issue of the new Scientific American will appear in the spring.

Since the first announcement of this change, many readers have written to ask how the new Scientic American will differ from the present magazine. A few of the more significant differences will be described here. Some of them will be physical: The number of pages in the magazine will be considerably increased and its design and typographical style extensively revised. More important, however, will be a massive change in editorial content.

The Scope of the New Magazine

The present Scientific American, as indicated on the cover of this issue, is limited to reporting the progress of industry. The editorial content of the new Scientific American will be limited only by the limitations of science. This principle requires a brief definition of the scope of science.

The classical divisions of science are the physical sciences (e.g., physics, mathematics, astronomy and various departments of geology) and the biological sciences (e.g., zoology, botany, genetics, biochemistry). To these have been added the social sciences, taking in specialties such as anthropology, archaeology, economics and even political science.

Two other classifications of tremendous importance have been added to the traditional divisions of science by practical usage. One is medicine, the methods and functions of which are often separate from the biological sciences. The other is engineering-technology, the art of applying science to the benefit of large numbers of people.

These five major partitions of science outline the scope of the new Scientific American. The Scientific American will publish articles on the physical, biological and social sciences, medicine and engineering-technology. Each of these divisions, furthermore, will be covered in about equal proportion.

Fundamental and Applied Science

The divisions of science provide a bare skeleton for the editorial content of the new Scientific American. How the skeleton will be clothed is largely the business of the editors and scientists working in close collaboration. There are, however, a few important attitudes toward this job which should be mentioned.

In addition to its formal organization, science is divided into two major enterprises. Part of the total effort of science, generally defined as fundamental research, is occupied with investigating the unknown. The rest, under the name of applied science, adapts this knowledge to practical use.

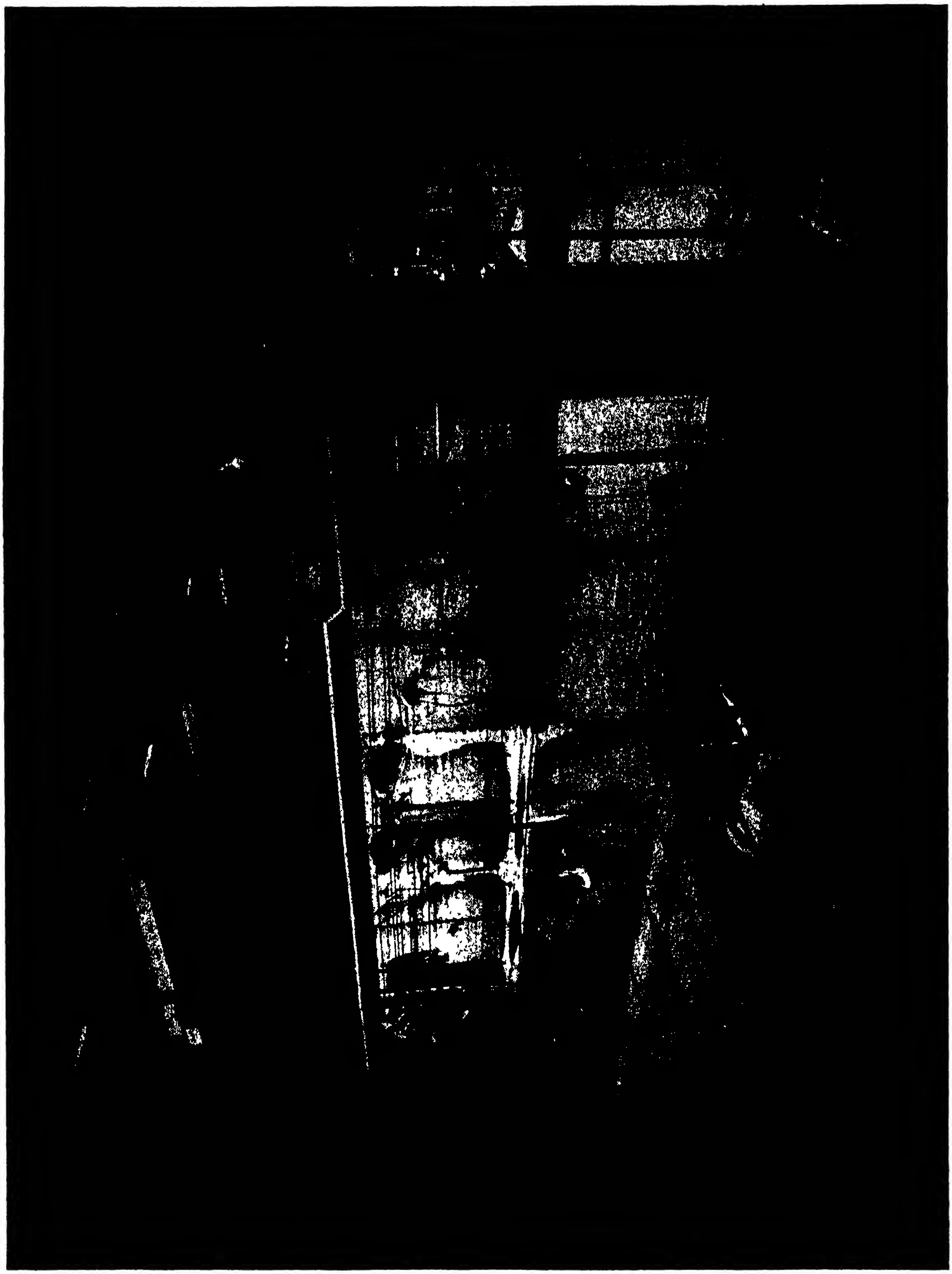
In the past, fundamental and applied science have often been sharply separated. Today, however, the continuous acceleration of scientific progress has largely obliterated this gap. The discoveries of fundamental science proceed almost at once to their applications, often with unpredictable social effects. One of the primary responsibilities of the new Scientific American will be to report such discoveries as they occur, thus preparing the intelligent but uninformed layman for their impact on his daily life.

Reporting in Context

Another basic responsibility of the new Scientific American is projected by the fact that the individual projects of science, like all other human activity, are an integral part of a larger whole. The Scientific American therefore must devote a special effort in articles on advances in science to relate this progress to the rest of science. It must furthermore publish articles reviewing whole departments of science, illuminating the interrelationship of their parts.

The present work of science is also related to an historical whole. The Scientific American must place each of its articles in their proper historical perspective. It will also publish articles dealing solely with episodes in the history of science.

These various approaches will provide a considerable variety of writing in the new Scientific American. All of them, however, will be directed to one end. This is that the Scientific American be a faithful reflection of the mind of science.



A high-purity oxygen producing unit. This unit will produce approximately 150,000 cubic feet of 99.5 per cent liquid oxygen per hour

OXYGEN IN STEELMAKING

The Gas Plainly Can Increase Steel Production. What Are The Limitations in Its Practical Application?

By William Mann

IN THE YEAR 1801 the brilliant young Philadelphia chemist, Robert Hare, was trying to make a flame as hot as possible in order to fuse some refractory substances. As a source of fuel he had already used the recently-discovered gas hydrogen in air mixtures, with a certain degree of success. It occurred to him, however, that if only about one-fifth of the atmosphere takes part in an exothermic combustion reaction, as the great Lavoisier had said, it was probably advisable to get the inert four-fifths out of the way. Whatever the fuel, the resultant flame would obviously be hotter if a considerable part of its heat were not wasted in raising the temperature of so much atmospheric baggage which contributed nothing to the reaction. This extraneous material was, of course, nitrogen.

The youthful scientist accordingly obtained a supply of pure oxygen from chemical sources and combined it with hydrogen in a "blowpipe." With this new instrument Robert Hare was able to melt platinum, to the great astonishment of a distinguished visitor to his laboratory at the University of Pennsylvania. This visitor was Dr. Joseph Priestly, who had discovered oxygen some years before. Priestly was astonished partly by the phenomenon, which had baffled prominent European scientists for years, and partly by the fact that the demonstrator was only 20 years old.

$100,000,000 TAKEN FROM THE AIR — The importance of this observation did not pass unnoticed, but for many years not much could be done about it. The fact is that a great many industrial procedures work well enough in their normal bath of 20 per cent oxygen, and industrialists, like the rest of us, are inclined to leave well enough alone. Besides, a great many related developments were needed before pure oxygen could come into full use. Notable among these developments was the making of refractory materials able to withstand the higher temperatures.

The small-scale pure oxygen industry of the 19th Century supplied the modest needs of the oxy-hydrogen flame in soldering platinum, in making laboratory vessels of fused quartz and in the projection apparatus known as the "lime-light." It was rather expensively based on chemical or electrolytic methods of production. Minor amounts were used in chemical industry and in hospitals. But the great increase in the use of the oxy-acetylene torch for welding and cutting metals in the early part of the 20th Century, together with related uses that have recently evolved such as scarfing and heat-hardening of metals, have made the manufacture of compressed oxygen taken from the air a large and important industry. It is said to be now worth over $100,000,000 per annum in the United States alone, with every indication of rapid increase.

Present expectations are that this increase will come from the use of a high-purity (99.5 per cent) or a low-purity product (about 90 to 95 per cent) in the metallurgical and chemical industries. More specifically, it will probably come in those sections of these industries which have operated heretofore with air, the natural 20 per cent oxygen reagent. There are many variable factors involved, economic as well as technical. Although certain scientific advantages seem assured, the details of application are far from definite, and certain new problems have arisen, as we shall presently see. Moreover, it has not yet been definitely determined what degree of purity is best for each phase of oxygen utilization in these

new fields. But much progress has been made and large-scale experiments are continuing in a general atmosphere of optimism that the difficulties that exist will eventually be overcome.

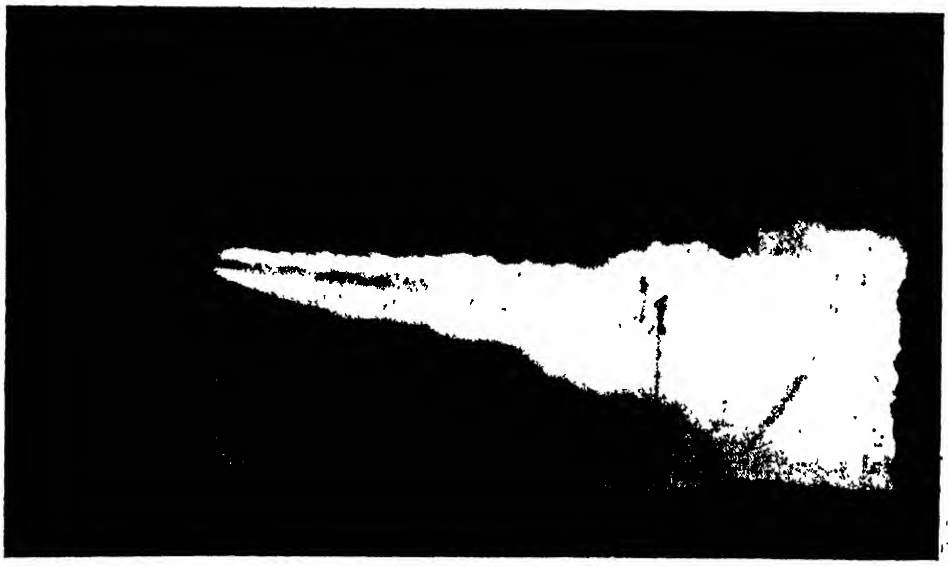
In this paper we are concerned primarily with applications of oxygen to steel-making. It should be mentioned, however, that the non-ferrous metals industry is also conducting experiments in this field and that large-scale applications in the chemical industry are far beyond the pilot plant stage. At Brownsville, Texas, a plant said to be the largest oxygen producer in the world is rapidly being completed for Hydrocarbon Research, Inc. It is scheduled to begin production early in 1948. This plant is designed to produce 48,000,000 cubic feet (some 2000 tons) of 95 per cent oxygen per day. It is planned to use this enormous amount of oxygen in the partial oxidation of 68,000,000 cubic feet of 1000 B.t.u. natural gas by the Fischer-Tropsch method. Theoretically, this will make approximately 2800 barrels of 80-octane gasoline, 1200 barrels of Diesel oil and 150,000 pounds of crude oil daily. An even larger plant is projected by the Stanolind Oil and Gas Company at Tulsa, Oklahoma.

OXYGEN AND STEEL — In the steel industry very pure oxygen (99.5 per cent) has long been used in relatively large amounts for cutting and welding operations and for scarfing of billets. Steel billets must be cleared of adherent foreign matter before rolling, otherwise imperfections will arise in the finished plate or sheet. For these uses high purity is still considered necessary. But oxygen for enriching air in blast furnace operations (from the usual 20 per cent up to 26 or 30) need not be very pure. A purity of 95 or even 90 per cent will do admirably for this purpose. This difference makes production much easier and is said to reduce the cost of the oxygen to about one-tenth. The same reasoning applies to the other branches of the steel industry, to Bessemer converters as well as open hearths. According to published data on Russian experience with Bessemer converters, the duration of a blow is reduced from 15 minutes to one minute by use of oxygen instead of air. In the open hearth, it is definitely known that enrichment with 90 per cent oxygen achieves higher temperatures which shorten the over-all cycle by greatly reducing scrap melting time.

A great deal of study has long been given to the use of oxygen in the steel industry of many nations. In Belgium it was tried in open hearths and blast furnaces over 30 years ago. Considerable data have been reported in recent years from Germany; Russian authorities are talking about converting their entire steel industry to oxygen operations at an estimated cost of $2,000,000. For this large quantity of rubles Professor Peter Kapitza expects to reduce the cost of steel making by 25 to 30 per cent. He is an able man and may very well achieve his purpose. Professor Kapitza has done fundamental work in the field of oxygen liquefaction. His pioneering in connection with the Kapitza low pressure turbine is probably the main source of the remarkable enthusiasm for new applications of oxygen that exists in Russia today, where a technical magazine named *Oxygen* is entirely devoted to discussion of the production and new applications of this element.

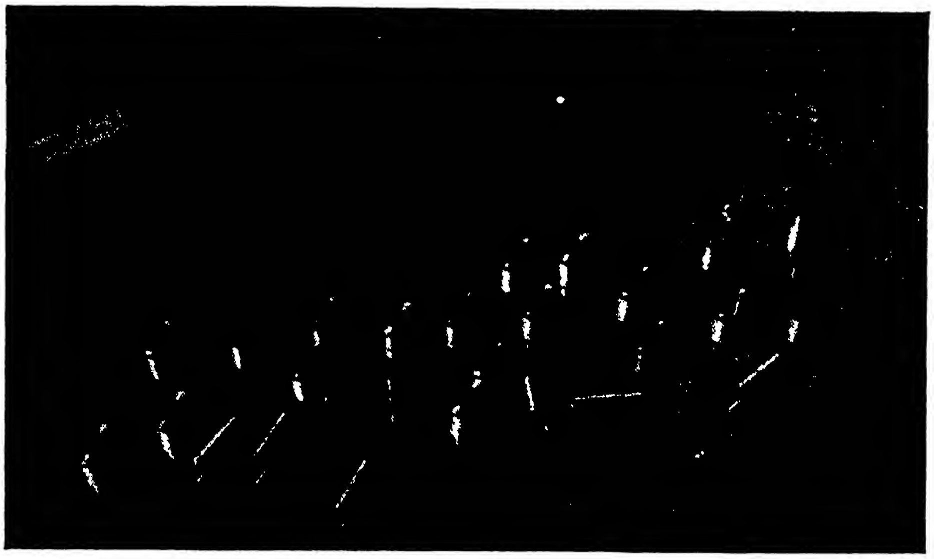
ADVANCING WITH CAUTION — Despite a general feeling of confidence in ultimate benefits from oxygen, which seems fully justified, the American steel industry has made no revolutionary changes, but has gone ahead cautiously since the end of the war. With the coöperation of oxygen producers, fundamental exploratory experiments have been conducted to find out how well the use of oxygen pays in the over-all picture of steel production. It has been estimated that if all of the 255 blast furnaces in the United States were to use oxygen enrichment up to 25 per cent (without increasing the volume of the blast), about 900,000 cubic feet of 95 per cent oxygen per minute would be required. This gives an idea of the size of possible requirements even by this relatively mild enrichment, which is said to have no detrimental effect on refractories.

Overlooking for the moment the expensive changes that may be required by new engineering design and improvement in refractories, there are at least



An oxygen-enriched flame being injected into an open hearth furnace. Enriching the flame results in higher temperatures which reduce the over-all cycle by shortening considerably the melting time of the scrap

Right. Assortment of laboratory and field auxiliary and field burners. Laboratory models are distinguished by the absence of connections for water cooling and steam atomizing



Left. Main burners are equipped with removable fuel pipes (upper openings) and interchangeable oxygen nozzles (lower openings). Extra nozzles in front of burners vary in capacities from 15,000 to 70,000 cubic feet per hour

two advantages that may reasonably be expected from use of oxygen in the open hearth furnace. By enriching the combustion air during the charging and melting, this period is shortened; by increasing the temperature of the reacting elements during the refining period these decarburization reactions are also improved and speeded. As a result of extensive tests conducted by the Republic Steel Corporation over a period of months, it has been reported that these advantages actually cut in half the time required to produce a heat of steel. Experiments were conducted in two of Republic's 14 open-hearth furnaces in the Cleveland district plant. Oxygen was applied directly to the bath by impingement on the surface at high velocity with excellent results. The lance method of introducing oxygen into the bath was employed in most of these tests.

The Wheeling Steel Corporation reports that oxygen introduced at high pressure directly into the open hearth bath by means of pipes inserted through the wicket holes has produced heats containing very low carbon and has accomplished savings in time and in fuel. Indications are that the quality of the steel produced is also improved. There is a definite saving of fuel and time, and a marked acceleration in carbon reduction rate. The study of optimum conditions is being continued.

It is a matter of considerable importance in this work that the charging of scrap should always be more rapid than melting in order to prevent damage to the furnace lining. The presence of some cold charge protects the roof and side walls of the furnace. As evidence of the high temperatures reached in this process and of the need for careful standardization of the design and equipment, a pipe inserted 30 inches below the surface of the steel to introduce oxygen will burn up at a rate of over two feet per minute. However, by inserting the lance to the slag-metal interface only, some plants have developed methods of extending its life to periods over an hour. The engineers of The Linde Air Products Company have developed a remarkable water-cooled jet device for this purpose. These have relatively long-lasting changeable nozzles from which a stream of oxygen ranging from 3000 to 70,000 cubic feet per hour can be issued.

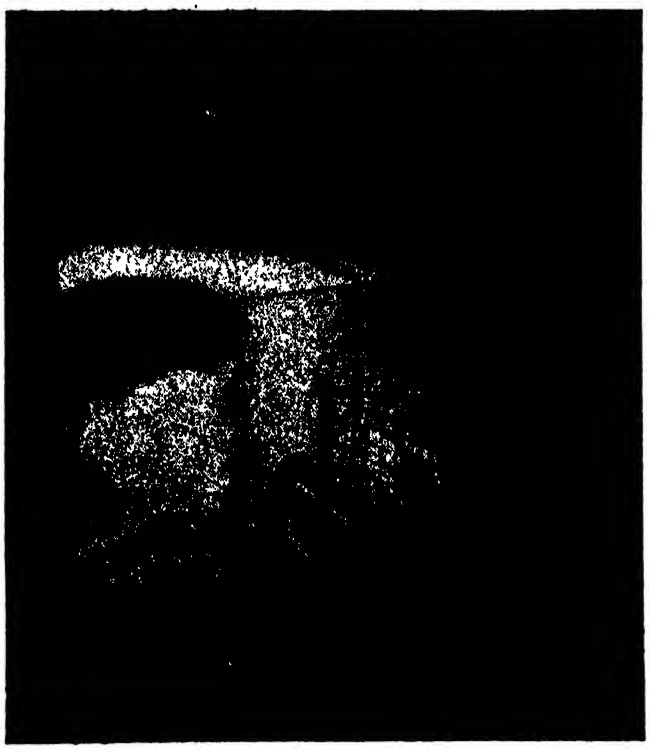
The Steel Company of Canada at its Hamilton, Ontario, furnace found that when oxygen was used increases of 20 to 40 per cent in capacity were possible. Under these conditions, eight to nine hours

had previously been consumed in charging and melting down. By using 1000 cubic feet of oxygen per minute mixed with the normal air flow, the charging and melting down time can be decreased by as much as one to three hours. Fuel consumption per pound of metal is also decreased (by about 8 per cent), the cycle is significantly shortened, and the control of flame characteristics and distribution is much improved. In one test reported by this plant on a 67-ton open hearth, the carbon content was reduced from 0.58 per cent to 0.09 per cent in 24 minutes. Six thousand cubic feet of oxygen were consumed in this operation.

The commercial producers of oxygen have naturally taken a leading part in this development. For instance, The Linde Air Products Company has coöperated with steel producers in conducting oxygen performance tests in more than 7000 heats in 34 furnace shops, and this work is still being carried on. The results of these experiments confirm the fact that the periods necessary for scrap melt-down and for refining in the open hearth are definitely shortened by significant amounts. Very high purity liquid oxygen was used in these tests, as it was provided at a price which made the tests economically practical. But, anticipating an increase in the use of oxygen of lower purity, Linde has had in operation for over a year a plant capable of producing 200 tons of 90 per cent gaseous oxygen per day. At the present writing, and until the Brownsville plant goes into production, this is probably still the largest single unit ever built.

Linde engineers have developed a number of new burner designs, and the non-consumable device for adding oxygen already mentioned; and to open hearth practice they have contributed to the new idea of direct scrap melt-down with a high velocity jet of oxygen. Air Reduction and the Koppers Company have also actively engaged in this experimental work, notably in coöperation with Bethlehem Steel. And other oxygen producers have done important work too.

This end burner is being tested in a thirty-foot long brick-lined test kiln



OXYGEN AND THE FUTURE OF STEEL — Oxygen plants for use with steel operations are being built in a number of American steel mills. Some are buying delivered oxygen, and a number are leasing or buying mobile units for liquid oxygen production. These developments and the related improvements in engineering design may not require an expense as large as the Russians say they expect to spend for their revolutionary steel developments, but when it comes to revolution we can hardly expect to compete with these experts. Nevertheless, it seems reasonably safe to predict that an oxygen-for-steel industry of considerable importance will develop in the United States. The serious smoke problem that often arises when oxygen is introduced, especially in high carbon ranges, will probably be licked in time. In Bessemer converters the use of oxygen would obviously eliminate the danger of the product being saturated with nitrogen and hydrogen. In the production of a ferro-chrome and ferro-manganese the higher temperatures provided by oxygen enrichment are especially advantageous.

Up to the present most applications have been directly applied to normal ores and conventional methods of steel production. A steel plant is a complicated industrial organism which has evolved over the years in an integrated fashion, tied to the use of certain fuels, certain ores and to conventional equipment all bathed in a sea of 20 per cent oxygen. This organism cannot be expected to adapt itself to important changes in any of these important factors overnight. If one part of the mill's work is speeded up by use of high-purity oxygen, say, it may result in upsetting certain other parts, at least temporarily. For instance, if scrap handling and charging facilities cannot also be speeded up, the accelerated rate of melt-down and refining in the open hearth work mentioned above may be only a nuisance until a new rhythm is established. But once over this hump, which has real economic and technical bases, the benefits of oxygen will probably begin to pay off.

From the standpoint of raw materials, some authorities foresee the time when cheap oxygen will make it feasible to work discarded iron pyrites tailings and poor ores, especially in remote northern or even Arctic areas where fuel is not readily obtainable. As the reaction between iron and oxygen is an exothermic one, practical methods may be worked out to make the ore itself supply at least part of its own fuel, as when a high velocity oxygen stream is applied to pre-heated scrap or to the jet cutting of carbon steel. It is predicted that mobile oxygen units could make it feasible to burn these low-grade ores and cut down coal requirements to a minimum. The supply of high-grade iron ore in this country is reaching an ominously low point. The time may come when such proposals, despite their obvious drawbacks, may seem very attractive and practical. Low-cost oxygen may provide the answer for low-grade ore.

ONE THIRD OF WOOD

Editor's note: The January issue of the Scientific American carried the first instalment of the following article, describing problems in the analysis and utilization of lignin, the second major chemical constituent of wood. Some lignin, Dr. Glesinger pointed out, is burned as fuel in pulp plants or used to make synthetic vanilla. Most of it, however, is flushed into streams as waste. The second instalment of Dr. Glesinger's article explores some of the research which may still make lignin a valuable raw material. Both instalments will appear in *The Coming Age of Wood*, to be published in the spring by Simon and Schuster, New York.

Cellulose and Lignin Are the Main Chemical Constituents of Wood. Cellulose Has a Vast Variety of Uses. Lignin Has Relatively Few. Second of Two Articles Describing Problems and Progress in the Utilization of Lignin

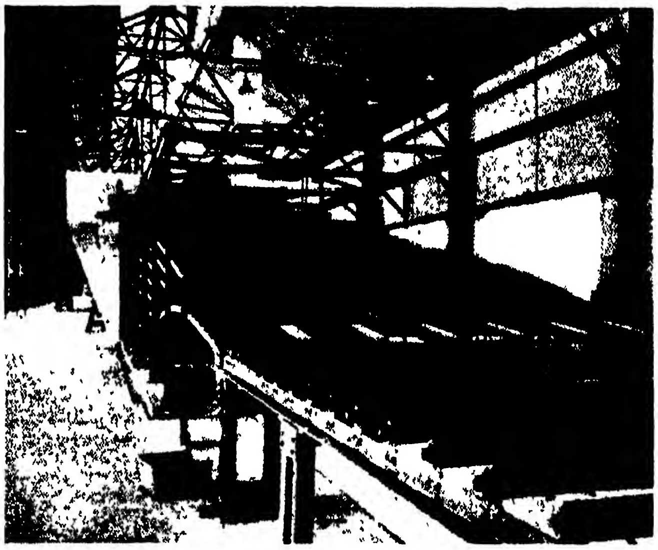
By Dr. Egon Glesinger

Director, Division of Forest Products,
United Nations Food and Agriculture Organization

ONE MAJOR and hopeful line of attack on the problem of finding new uses for lignin is hydrogenation, the process of adding hydrogen atoms to carbon compounds. Achieved by high temperatures and huge pressures, hydrogenation results in profound and diverse changes in the structure, appearance and properties of the chemical raw materials treated. Best known is the hydrogenation of coal, which supplied more than half of Nazi Germany's gasoline and lubricating oils during World War II. In the petroleum industry, hydrogenation is the essence of the various cracking processes used to extend the yield of gasolines from crude oil and to produce the superfuels of aviation.

Lignin hydrogenation has so far been conducted largely in the laboratory pressure bombs of the U. S Forest Products Laboratory at Madison, Wisconsin. It has produced yellow liquids of high viscosity that look and smell exactly like the basic fractions of crude oil. Fractionation and other chemical treatment of these liquids yield, first of all, a host of mysterious substances of no known immediate use, but apparently great promise: phenols, the parent material for most thermosetting or heat-resistant plastics; volatile as well as heavy lubricating oils; and, finally, most important of all, the hydrocarbon mixture known to the British as petrol, to the Americans as gasoline and to the rest of the world as the precious fluid that drives engines and wins wars.

FUTURE OF HYDROGENATION — As to the future of lignin hydrogenation, *Lab* declares: "These processes have not passed the pilot-stage and, therefore, cost figures for a commercial plant are unknown"—a polite way of saying that the cost of lignin hydrogenation is prohibitive. Yet, this is true of all synthetic processes in the laboratory period of their development. In 1937, I heard no less an authority than Hjalmar Schacht say that it would be madness for Germany to produce Buna rubber if she had any way of getting and paying for natural rubber. At the inception of the United States synthetic rubber program in 1941, the cost per pound of Buna was from thirty to forty cents. Today, its prospective market price of ten to fifteen cents is fully competitive with the prewar average of fifteen cents a pound for crude natural rubber delivered at United States ports.



A sheet of composition board coming out of the processing machine. Lignin is the bonding material which gives the board its strength

Conclusion-jumping on lignin hydrogenation usually begins with an unwarranted comparison of the first meager laboratory results with the high yields and low costs of the hydrogenation of coal and oil. It is also pointed out that the Nazis, despite their mastery of wood chemistry, made no attempt to secure from lignin relief for their war shortages of motor fuel and lubricants. Obviously, the vast and successful experience of coal and oil chemistry sets stern competitive standards for the future of lignin, and the industries that live on these minerals make the most of the situation. But, as long as the exact

nature of lignin remains unknown, all such conclusions are premature.

The chief accomplishment of lignin hydrogenation to date is that it has produced samples of the materials lignin can yield. It has established that lignin is an aromatic compound in the chemist's vocabulary; that its molecule is a "ring" structure in contrast to the linear or fiber-shaped structure of the cellulose molecule. As such it is closely related to the hydrocarbons of coal and oil and responsive to the tricks and devices by which organic chemistry is able to break down and reconstruct these materials into a variety of useful products The trouble from here on seems to be that lignin is as delicate as a medieval virgin and is adulterated by the most mildly curious glance.

NOT JUST ONE LIGNIN -- Apparently, there is not just one lignin, but several lignins. It will probably be found that some are no good at all and that others possess all of the exceptional properties attributed to lignin. This suspicion is supported by the first products of lignin hydrogenation. The thick yellow liquid contains, in addition to oils and resins which have been identified, many mysterious unknown substances Some will be waste products: others may surprise the world. The unknown qualities in lignin raise the further possibility that hydrogenation may turn out to be an altogether wrong approach. Its exploration, however, may lead to the discovery of new and simpler processes especially adapted to lignin.

There is promise, for example, in a revolutionary new pulping process now under laboratory experiment. Its reagent is an organic solvent, instead of the crude caustics and acids of the sulfite and sulfate industries. The gentler and more precise action of the organic solvent yields two prime products instead of one. Cellulose, the first, comes out as "holocellulose," with the natural cellular structure of the fiber almost intact. Lignin is the second, and it also shows the virtues of organic chemistry. Extracted from solution by means of another organic solvent, ketene, it forms an interesting series of compounds. Basically they are white, as lignin compounds should be, and they exhibit interesting signs of chemical life. There

	Gasoline (Million gals.)	Alcohol (Million gals.)	Pulp (Million tons)	Lumber (Million bd. ft.)
From 160 million tons of wood converted into fuels	4800	9600		
From 80 million tons of pulpwood	2400	2000	40	
From 80 million tons of logs	1200	2400		40
From 320 million tons of wood	8400	14000	40	40

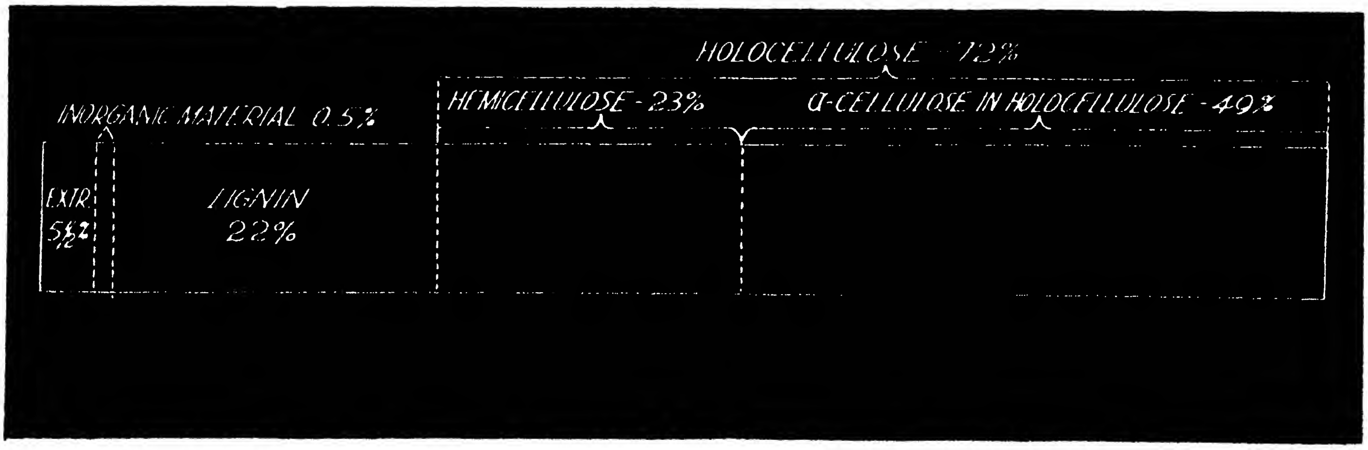
In sum:	
22,400 million gallons of fuel @ 10¢	2.24 billion dollars
80 million units of pulp and lumber @ $25	2.00 billion dollars
Total	**4.24 billion dollars**

is no justification, again, for predicting costs or even products at this early stage of development, but there is also no doubt that here is something worth public exploration.

No matter how it is ultimately processed, lignin has a basic economic advantage because it is a waste material. Even if new and more expensive pulping methods had to be adopted to secure reactive lignin, the major cost of its extraction would always be borne, as in the case of coal tar and producer gas, by other self-supporting products. Since lignin as a raw material will cost next to nothing, a profit of only one cent a pound will be enough to make it a bonanza.

Lignin is justly regarded as the key to the future of wood chemistry. As long as wood chemical industries are unable to process lignin to commercial advantage, their position in coal and oil industries will remain that of the country butcher competing with the Chicago meat packer who exploits everything but the squeal. With the handicap of lignin as a by-product nuisance, it is remarkable that the wood-chemical industries—more correctly, the cellulose-converting industries—have not gone to the wall long ago It is even more remarkable that wood pulp

A graphic representation of a chemical analysis of wood. Here cellulose is broken down into low-grade hemicellulose and high-grade alpha cellulose



is highly profitable, wood-sugar alcohol is fully competitive and that other products of wood chemistry are making steady progress. The fact that to date lignin is almost a dead loss, however, has seriously hampered wood chemistry and kept its total turnover at about twenty million tons a year.

LIGNIN OPENS THE DOOR — When lignin chemistry becomes a reality, it will immediately increase the annual end-product capacity of wood chemistry by 50 per cent without requiring a single extra ton of wood to the quantities now processed. It will, furthermore, make the entire operation so much more profitable and lead to such substantial reduction in unit cost, that the barriers that have held back wood chemistry will collapse like the walls of Jericho. Soon this industry will find itself processing ten, twenty or fifty times its present wood tonnage and flood the world's markets with inexpensive supplies of many of the things they need.

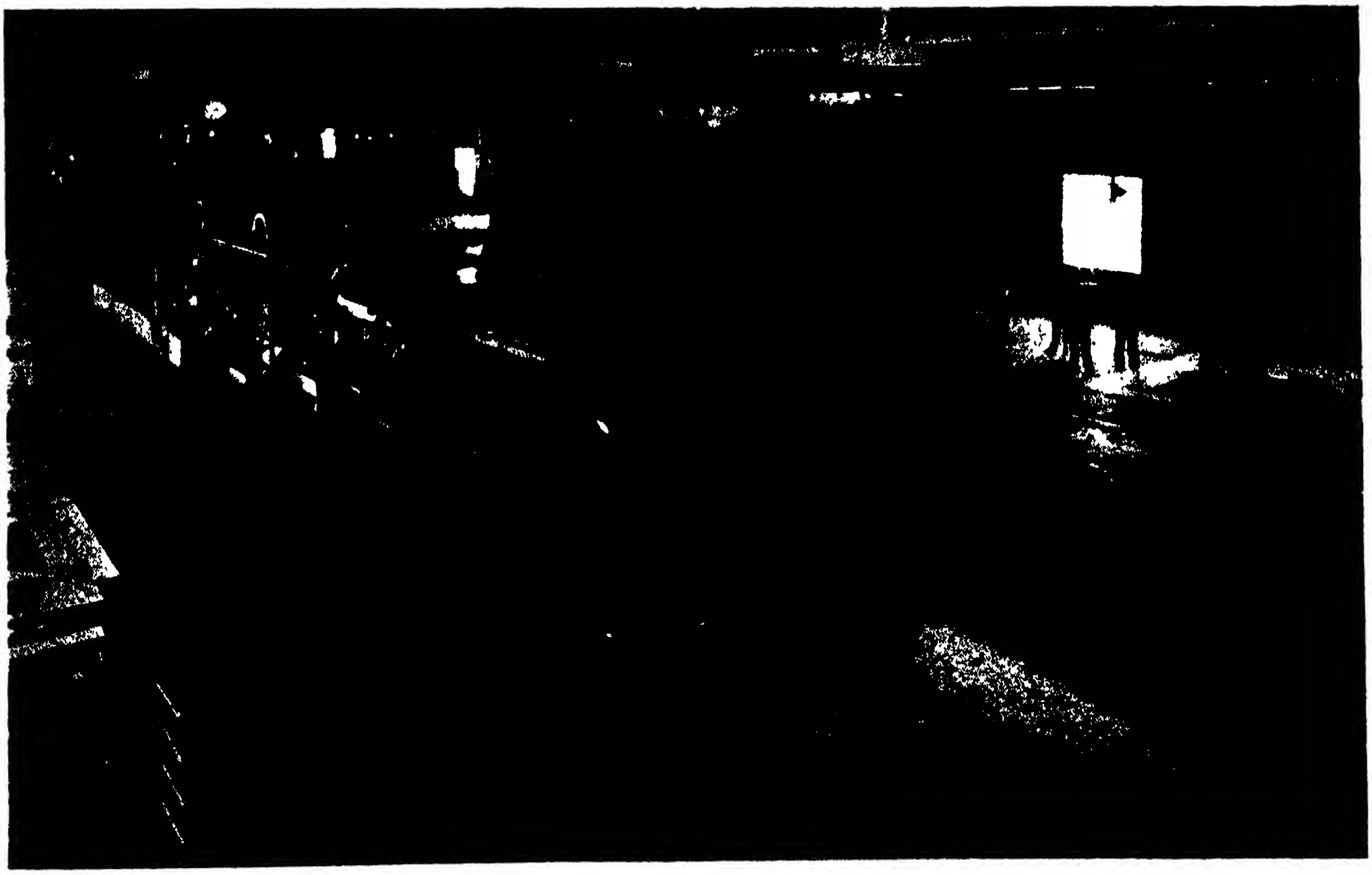
Speculation on the consequences of lignin conversion on an industrial scale provides stimulating mental exercise. Let us make the reasonable assumption that the same ton of wood that yields sixty gallons of alcohol via the Eugene, Oregon, process might produce an additional thirty gallons of lignin-base gasoline. Let us further assume that Europe's forests, not including Russia, could produce annually one ton of wood per acre, of which one half would be diverted to the production of liquid fuel, a quarter to cellulose conversion, and the remaining quarter to lumber. The result, including the waste lignin of the latter two industries, is shown in the accompanying table

By this calculation, Europe's 320 million acres of forest could produce primary goods worth 4240 million dollars, or three times the value of their present output. They could permanently supply Europe with more motor fuel than the United States consumed in 1937, and revolutionize the economic structure and living standards of the old continent and its 500 million inhabitants.

Applied to the world's 8000 million forest acres, the same assumptions yield truly breath-taking figures The annual forest harvest could yield, in addition to 2000 million tons of pulp and lumber, more than 400,000 million gallons of motor fuel, or five times the world's prewar production of crude oil. Other lines of calculation give equally impressive results, but it is not my intention and even less within my power to paint a Utopia. The illustrations are useful, however, for projecting the potential significance of lignin not only for the forests but for the entire world.

Gasoline and lubricating oils from lignin are still far away. How far away is best demonstrated by the fact that recent industrial development of lignin has taken an entirely different course. It has led to the rise of a large industry engaged in making a variety of "ligno-cellulose" products—known by their less scientific name of "wood plastics"—in which the natural association of lignin and cellulose is maintained, but modified to meet a wide range of material specifications.

An overhead view of a lignin plastics processing machine. The product, in sheet form, is dense, hard and strong



TUBES IN MANUFACTURING

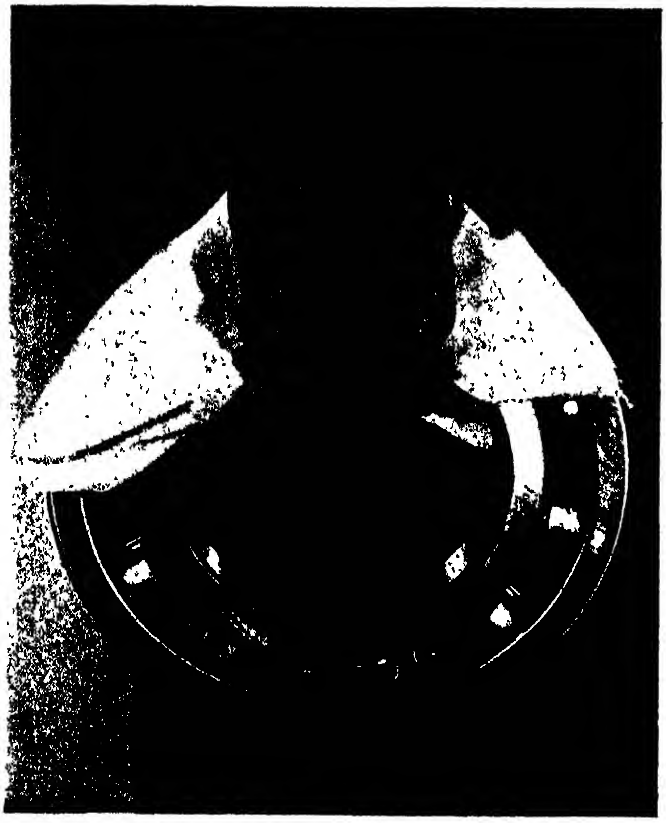
Tubing Today is Much More Than Pipe. Among Other Things It Is Becoming a Stock as Basic Sheets or Bars

By Edwin Laird Cady

THE ORIGINAL industrial uses for tubing were based on no more than the fact that tubes have holes through their middles. The holes could be used as passages through which liquids or gases could flow or wires be conducted. And when smaller parts needed straight bores the holes avoided drilling and other machining operations.

Within the past few years another consideration has increased the importance of tubing. High alloy steels and some of the other alloys are sluggish in their response to heat treatment. The centers of thick and solid bars may remain soft, fibrous or poor metallurgical structures after the bars are heat treated. Worse still, there can be residual strains between the interiors which do not "take" the heat treatment and the exteriors which do. In tubular shapes, however, there rarely is metal section too thick to respond to heat treatment. Tubes can minimize this problem and sometimes can even eliminate it.

The races of this anti-friction bearing are made from sections of tubing. This permits far greater control of quality



The physical working of metal is another case in point. Tough alloys resist the wroughting processes which do so much to strengthen and refine metallurgical structures. They also tend to confine the results to the exteriors of thick sections. In the manufacture of tubing, however, both interior and exterior of the tube automatically undergo intensive physical wroughting. Either a piercing tool must be forced through the middle of a billet to make the bore of the tube, or wrought flat stock must be bent until the edges meet for welding into tubular shapes. The bore of the tube, then, is at least as thoroughly worked as the exterior, and in most instances is worked even more.

ROCKING PROCESS — The rocking process developed by the Tube Reducing Corporation is an extension of wroughting. Originally this method was intended to solve the problem of making tubes in different sizes. Tube piercing requires highly expensive tools to manufacture tubing of any given outside diameter and wall thickness. Therefore only a few standard sizes of any given alloy were regularly made by any tube mill and were obtainable from stock in reasonable quantities.

The rocking process uses grooved rockers to squeeze tubes down over mandrels which are smaller than the original tube bores. Reductions in bore of five to one are practical, and even larger ones can be made. The lengths of the tubes are greatly increased, making possible the manufacture of sections as long as thirty six feet for fabrication in automatic screw machines. By this compacting process the strength and grain structure of tubing can be greatly improved. The concentricity can also be held to within 5 per cent of the outside diameters rather than the 10 per cent which applies to the manufacture of many tubular shapes. With this accuracy the makers of machined tubular parts often do no more than machine and grind away the amount of stock which ordinarily would be removed

Right. Such small parts as these are very economically fabricated on automatic screw machines or by means of swaging

Below. Tubular shapes are preferred members of weldments

to eliminate surface imperfections. The finished parts will be to the required accuracies and concentricities.

The makers of anti-friction bearings were among the first to take advantage of the increased range of tube sizes and the refined grains of worked tubing. The steel of which ball bearing races are made is difficult to machine and too expensive to waste as chips from solid bars. For extremely hard service, such as bearings must withstand, tubing also is easier to inspect for flaws.

Metal tubing may be conveniently inspected by X-rays, by xyglo oil techniques and by means of ultrasonics. When tubing is cold drawn or cold worked by the rocking process, nearly all flaws may be detected before a tube is machined into bearing parts. But X-rays or ultrasonics can be used to eliminate the slight chance that there might be flaws which cold working did not reveal.

Tubular shapes are ideal for induction heating because they present smooth exteriors and uniform wall thicknesses to the induction coil so heat can travel rapidly through their wall thicknesses. The salt bath heating of tubing also is rapid because molten salt can bathe interior and exterior of the tube, heating both faces of the metal simultaneously Radiant gas burners of ceramic types can be applied to tube interiors for rapid heating. Tubes are also easy to heat by resistance because their uniform walls hold a balance between interior temperature and exterior radiation loss.

The ease of heat treating tubes leads to uses which might not be attempted with other forms. Tubes of stainless steel, for example, can easily be heated to the annealing temperature and quenched without spending more than three minutes in the critical range. Automobile makers give the same tubular part one heat treatment to make it stiff and tear-proof for machining, a second for welding, a third for bending after welding and a fourth to impart hardnesses and strength. Sometimes, by induction or salt bath methods, one end of a tubular part is heat treated for machining while the other is simultaneously treated for swaging or other deforming. Such operations would be impossible in other structural shapes.

IDEAL FOR WELDING — Tubular shapes are ideal for any method of welding or brazing. Their bores eliminate the problems of heating and cooling of excess metal. Cylindrical tubes are equally strong in all transverse directions and therefore do not tend

to pull out of shape when cooling. Tubes other than cylindrical are also surprisingly good in this respect Cylindrical shapes have excellent contours for automatic and uniform transfer and distribution of stresses if residual stresses remain within the welds

Welding and brazing as methods of manufacturing tubes are advancing rapidly. As practiced by the Republic Steel Company and the National Tube Company the weld is 100 per cent efficient and is under such completely automatic temperature and heat treatment control that there is no threat of carbide precipitation. Cross-crystallized compression welding, wherein the weld zone is metallurgically indistinguishable from the parent metal, has not been widely adapted to tube production but it is capable of producing welded tubes which are as adaptable as pierced tubes to the rocking process. The Bundy process, which makes tubes by continuous fusion joining of spirally wrapped strips, is solving problems of tube stiffness, directional strength, metallurgical control and corrosion resistance, but its products have not been adopted widely enough to estimate its full industrial future.

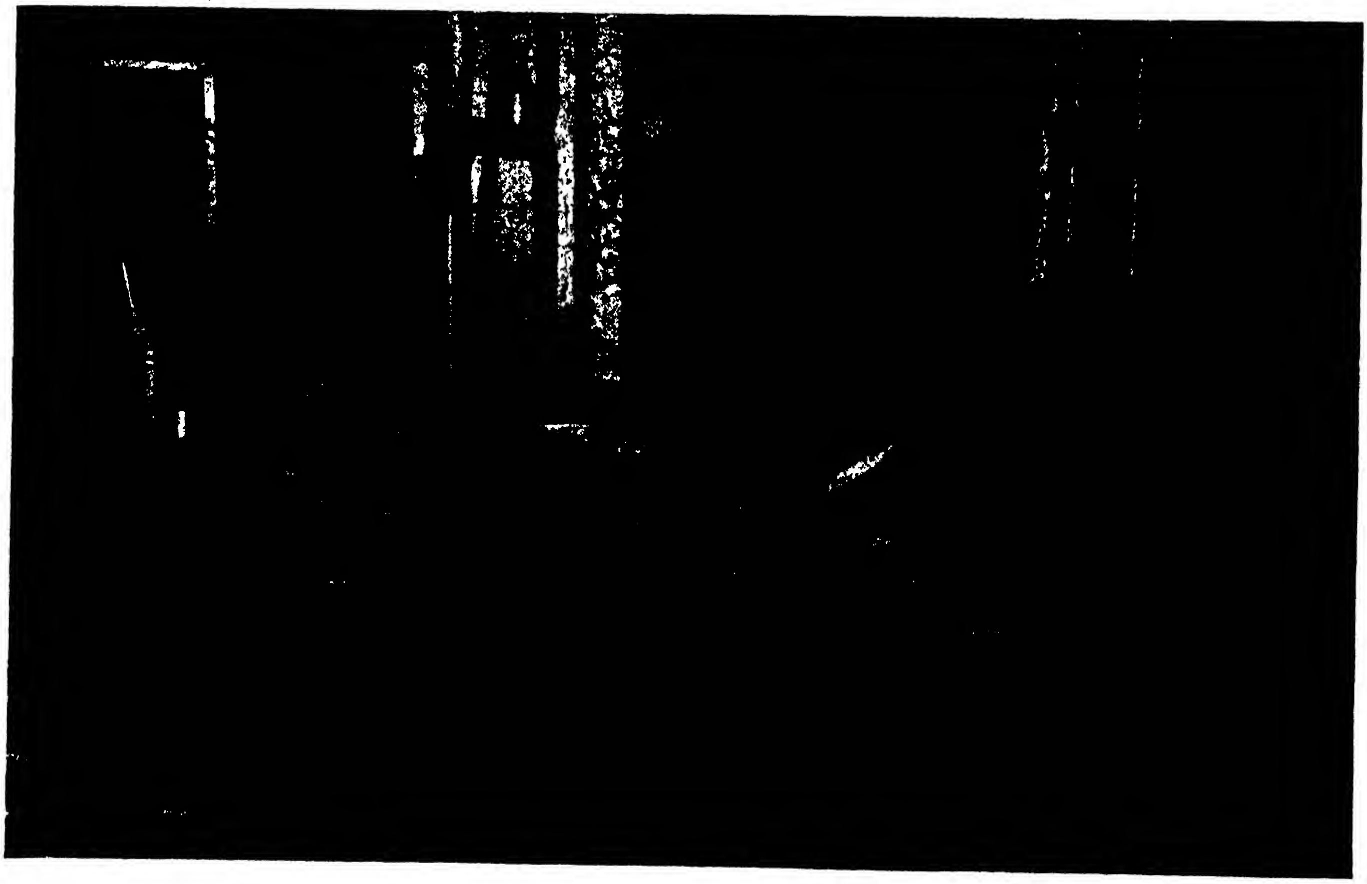
SILVER LININGS — Silver-clad or silver-lined tubes such as those made by the D. E. Makepeace Company begins as solid plates of copper or other base metal overlaid with solid silver plate. The finished tubes actually are extremely deep drawn shapes, good use being made of the high ductility of silver and the fact that silver readily recrystallizes after cold working. Silver solder may also be placed between the silver and base metal, the solder, acting as a wetting agent to promote interface contact, being squeezed out and recovered in the drawing process. Tubing clad with silver and other precious metals by this process is widely used in radar and radio and is improving many of the installations of corrosion-resistant pipes and faucets in chemical plants.

Tubes of either pierced or welded construction are being lined with enamels. No tube of less than four inches inside diameter has been found commercially suitable for outright porcelain enameling of the bore. But the rapid advance of special enameling steels which may be welded into tubular shapes, the increased availability of titanium oxide for enamel and the experiments with induction heating for baking the enamel uniformly, may make much smaller porcelain lined tubes available in the near future And other enamel linings, such as those made by the Interchemical Corporation, are proving highly effective.

Centrifugal casting of tubes as practiced by the U. S. Pipe and Foundry Company is producing cast tubes of qualities suitable for rocking and other cold working. One metal is being cast inside another, such as a soft steel suitable for bearings inside of a hard steel exterior suitable for abrasive wear. The process is under intensive development, with its full potentials not even estimated as yet.

Thus the entire tubing industry is developing rapidly into markets which are established by the fact that tubing, in addition to being a useful conduit is able to solve thousands of problems of product design and production.

A piece of seamless tubing comes from the extrusion press



THE ARRIVAL OF POLYSTYRENE

By James R. Turnbull
Monsanto Chemical Company

During the War the U. S. Created Capacity To Make Styrene, Key Ingredient of One Kind of Synthetic Rubber. Now Styrene is Built Up To Polystyrene, Presenting Industry With Large Quantities of a Cheap and Versatile Plastic

THE WARTIME development of U. S. capacity to make synthetic rubber made an unexpected contribution to the store of raw materials available for manufacturing processes. During the war this country built plants to produce huge quantities of styrene, a key ingredient of GR-S synthetic rubber. It happens that styrene may also be polymerized into polystyrene, a cheap and versatile thermoplastic.

Polystyrene is already on its way to becoming the heavy industry of the plastics field. This year its production in carloads may exceed that of aluminum before the war. From a starting figure of 100,000 pounds in 1937, polystyrene production jumped to 22,000,000 pounds in 1945 and to 55,000,000 pounds in 1946. Experts consider it certain that installed capacity at the end of this year will top 150,000,000 pounds by a wide margin.

The technology of polystyrene, moreover, is constantly advancing. The Plastics Division of Monsanto Chemical Company, for illustration, recently announced a polystyrene variant called Lustrex which retains its shape after limited immersion in boiling water. With due caution, the company calls it a "scaldable" plastic rather than a "boilable" plastic. Lustrex opens the way to polystyrene's more extensive use in kitchen and dining room accessories, nursery items and surgical instruments.

Earlier, scientists of the same company produced a polystyrene plastic which glows after exposure to light from six to eight hours, doubling the after-glow time of prewar luminescent plastics. This material is now being used to mass-produce such items as house numbers, flashlight handles, switch plates, wall plug plates, door escutcheons and light pulls. A companion plastic is activated by ultra-violet lamps.

The plastics industry thinks so well of polystyrene that several suppliers of plastics materials have made heavy investments in styrene plants purchased from the War Assets Administration. Contracts with RFC's Office of Rubber Reserve, however, still give first call on the production of these plants to the nation's synthetic rubber requirements. One such plant was lost in the recent Texas City disaster, and the wreckage is now being cleared to make way for a new and more efficient plant.

The feeling of Rubber Reserve people is based on something more than a desire to see four good tires on every automobile. Shuddering as they think of the early days after Pearl Harbor, they want to maintain the plants which can guard the country against the emergency caused by the end of natural rubber imports. They also seek a guarantee against high natural rubber prices which might be arranged through price-fixing manipulations of foreign cartels. They reason that there is no better way to nail down these guarantees than to keep the styrene plants in operation.

Both spoons have been dipped into the bowl of scalding water. Spoon of standard polystyrene (right) crazes and distorts. Spoon of improved polystyrene is unchanged

The plastics suppliers, on the other hand, applaud the opportunity to engage in the manufacture of a raw material with polystyrene's market potential and capacity to enrich human life. On the basis of past performance, their faith in the product seems justified. One industry alone, the manufacture of home refrigerators, is expected to consume 8,000,000 pounds of polystyrene this year and 20,000,000 pounds next

year. Comparable amounts will be used by radio, television, toy, novelty and household appliance industries

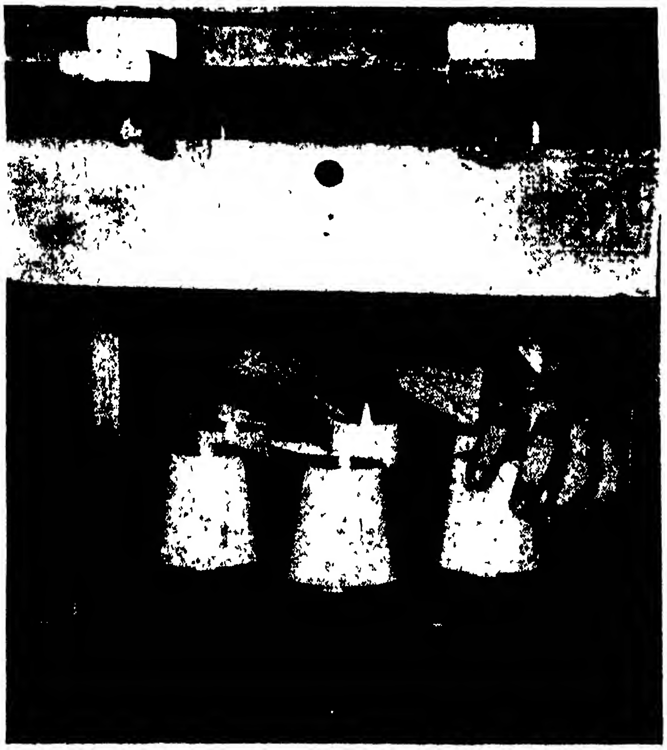
A THIN AND COLORLESS LIQUID — As it comes in tank cars to the makers of plastics raw materials, styrene is a thin and colorless liquid with an odor which suggests escaping gas. It is compounded with butadiene to make synthetic rubber. The plastics manufacturer reacts styrene with itself. The process involves the application of heat, transforming styrene from a liquid to a solid as clear and colorless as water

Polystyrene is produced largely without hand labor, a factor which helps to account for its low production cost and low selling price. It is brewed inside great kettles, tanks and retorts; even its color can be added by machinery. Generally the first man to see polystyrene molding polymer is the worker who loads it into fifty-pound paper sacks for shipment to injection molding plants.

One important reason for polystyrene's desirability is the fact that it is a thermoplastic. This means it can be used in injection molding machines, the fastest and most economical means of producing objects of plastic. In a 24-hour day the average injection molding machine can produce either 50,000 artificial gems, 25,000 clothes pins, 25,000 thimbles, 20,000 pocket combs, 10,000 compact cases or 5000 clock housings. As a mass production technique, this approaches the ultimate.

Hand labor is again almost entirely absent in injection molding. Raw material is converted to finished material without painting, enameling, die stamping machining or labeling When mechanical packaging is employed, the first person to touch a polystyrene item is the buyer. Color is inherent in the plastic material, eliminating the need for painting or enameling. Intricate shapes can be molded to tolerances of one ten-thousandth of an inch, doing away with the need for costly machining operations. The article or its maker can be identified by raised lettering.

Flower pots of polystyrene are rapidly stamped out in a single operation on this injection molding press



A laboratory technician measures the force required to break a sample of polystyrene on a physical testing machine

The injection molding machine is largely responsible for polystyrene's success as a raw plastic. The first injection molding machines were developed in Germany and introduced to this country only 11 years ago. A machine will range in cost from $6000 to $30,000, while the mold required to make any given part will add from $200 to $12,000 The size of the item manufactured is limited by the machine itself. The average injection molding machine is an eight-ounce unit, which means that in one operating cycle it can produce eight one-ounce objects or one eight-ounce object. The molding material is poured into a hopper, whence it goes into a heating chamber to be melted. From there it is squirted under tremendous pressure into the mold cavities which break apart to free the newly-manufactured item

WANTED AND UNWANTED QUALITIES — Like every other material, polystyrene represents a combination of wanted and unwanted properties. Its chief virtue may be said to be its adaptability to mass production in injection molding machines, a consideration which helps greatly to improve its competitive position in comparison to ceramics, the light metals, other metals and wood. Second in importance is the fact that polystyrene is priced far below competing thermoplastics. When it was introduced in 1939, polystyrene sold at 72 cents a pound. Today's price (in carlot quantities, for crystal molding polymer) is 24½ cents a pound. By comparison, cellulose acetate now sells at 48 to 50 cents a pound, butyrates and ethyl cellulose at 55 to 65 cents a pound, and methacrylates at 85 cents a pound. It should be stated, of course, that each of these lends itself to certain specialized applications more readily than does polystyrene. Yet in hundreds of general applications, polystyrene does as good, if not a better job.

The suppliers of polystyrene have indicated that

increasing manufacturing costs have, for the present, put the hope of a price decrease out of the question. It is known, however, that they are eager to pare polystyrene's selling price to the lowest consistent minimum. No one realizes more keenly that each downward notch will open new markets, bigger volumes and larger profits. At the same time, it is considered likely that polystyrene's competitive threat will inspire suppliers of other materials (*i.e.*, aluminum, magnesium, wood, bronze, glass, ceramics, etc.) to improve their processes and lower their costs. The winner will be the consumer.

Manufacturers of polystyrene say it has much more to recommend it than low price and adaptability to mass production. Another important factor, they state, is its low specific gravity, a property which stretches it 20 to 30 per cent further in many applications than other thermoplastics. Polystyrene's lightness is also an advantage over more conventional materials in itself.

Consider aluminum, for example. Light and ideally suited to markets which polystyrene can never hope to invade, it nevertheless has a specific gravity of 2.7 in comparison to polystyrene's 1.06. Thus on a volume-for-volume basis 1947's projected production of polystyrene will not be far under the aluminum industry's prewar record year of 615,000,000 pounds. Glass has a specific gravity of 2.6, zinc of 7.1, nickel of 8.7, copper of 8.9 and lead of 11.3. Even granting that each of these materials will always have its place in America's economy, it follows that it will always require from 2½ to 8 times as many pounds of them to fill a given cube than will polystyrene.

HIGH TENSILE STRENGTH — High on the list of remaining advantages is polystyrene's high tensile strength, greater than that of lead, zinc, glass and copper, but not quite as high as aluminum. Another factor is its crystal clarity and its large color range, still another is its chemical resistance to acids, alkalis and some solvents. Within certain temperature ranges, polystyrene has excellent electrical insulating properties. It does not lose strength at lower temperatures and it has a high refraction index which gives it sparkle.

The debit side of polystyrene will be mentioned here in its relationship to other thermoplastics only. Its impact resistance is considerably less than that of the cellulosic thermoplastics, giving the latter a pronounced advantage in certain applications (example gun stocks). It is attacked by aromatic hydrocarbons, including gasoline, which puts it out of the running for some automotive parts. If improperly molded, polystyrene tends to craze and distort to a greater extent than some of its companion materials. It also is less suitable than some other plastics for parts with metal inserts molded in.

Plastics manufacturers have contended that no material on the market boasts such a wide and diversified range of favorable factors and such a short list of limiting ones. The sales figures and the demand curves back up their statements. It is encouraging to them that research still has some distance to travel in the development of new uses for polystyrene.

In their effort to bring forth new plastics which have new superior properties, plastics researchers are conducting continuous experiments. Many of them are working with styrene monomer. This approach attempts to co-polymerize this low-cost material with some other plastic. As is to be expected, many of these experiments fail, with the development of superior properties being accompanied by inferior properties. On the other hand, some are being crowned with success. It is not beyond the realm of possibility to assume that mating styrene with other materials will create a plastic that can be boiled for hours or one that will have the structural strength of aluminum or another that will take metal inserts readily.

Products made of polystyrene already run a broad gamut. Some items are strictly functional, others are strictly decorative and most of them are a combination of the two. A few samples are refrigerator parts, clothes pins, artificial gems, thimbles, pocket combs, compact cases and clock housings. This list scarcely begins to scratch the surface. The volume uses now include buttons, trays, salad bowls, cutlery handles, measuring cups, tumblers, funnels, bottle closures, cosmetic containers, picture frames, photographic equipment, poker chips, bathroom tile, radio parts, refrigerator parts, adding machine parts, typewriter parts, bathroom fixtures and so on. Telesion lenses and screens have been successfully molded from polystyrene. So have fine-tolerance camera lenses. One molder is preparing to market fog-piercing yellow polystyrene lens which may be slipped over auto headlamps. An auto manufacturer is toying with the idea of molding an entire dashboard of polystyrene. Eighty-ounce battery case halves have already been made for aircraft.

Polystyrene has come a long way in a short time. It seems inevitable that it will go much farther.

Testing the hardness of polystyrene. The hardness is determined by the time required for each bubble to move in the two tubes

THE DOMAIN OF RADIO FREQUENCY HEATING

Another New Technology Has Become One of Industry's Accepted Tools. A Review of Its Principles and Applications

By T. P. Kinn
Westinghouse Electric Corporation

RADIO FREQUENCY heating has been accepted by industry as a new manufacturing tool because it results in better products made faster at less cost. Furthermore, it can sometimes do the impossible.

The evolution of radio frequency heating from its role of laboratory plaything less than a decade ago, can be traced through the many successful installations in industry today. Such varied applications as textile drying, curing and drying of rubber, bonding of wood and plastics, contour hardening, high- and low-temperature brazing, silver soldering, annealing and tin reflowing are but a few of the uses to which this new tool has been adapted, and still current developments represent only a small portion of the demand for this production technique.

The success of radio frequency heating compared to other methods can be computed from the balance sheet of industry itself.

By the use of radio frequency heating one plastic manufacturer shortened the curing time of his products by 91 per cent, cut mold costs by 66 per cent and maintenance costs by 80 per cent. At the same time he was able to increase production 20 per cent, save 12 per cent on materials and get 30 per cent longer life from the molds.

The steam oven method of curing foam rubber sponge mattresses required 30 minutes and each mattress was made in three sections which later had to be cemented together. The double bed mattress, as a single piece, was cured in six minutes by use of radio frequency heating. The quality was improved because of more uniform curing and elimination of the cementing process

After curing, the rubber had to be washed and dried. Drying with hot air alone required ten hours By using radio frequency heating for 90 seconds and hot air for one hour, drying time was reduced 90 per cent. Similar results have been achieved in the curing and drying of other rubber products

One manufacturer required seven men to silver solder an assembly of an angle, five saddles and a tube. Two operators were required to spot weld the five saddles to the angle and five men worked together to silver solder the tube to the saddles. Because gas brazing was so slow, successive brazing would have caused serious warpage. This five minute process was reduced to 10 seconds by brazing the pieces together simultaneously with radio frequency heating. Warpage was avoided by the speed at which the job was handled.

Placing plastics preforms in a dielectric heater. Dielectric heating cuts the cost of molded plastics and improves the quality of the product

TIN-PLATING STEEL — Before the war, steel strip was tin-plated by the hot-dip method . . . a process that required one and a half pounds of tin for each 100 pounds of finished plate. Handled in single sheet form, processing was slow, and as tin became a war-scarce commodity, shortage threatened the entire industry. To conserve available stocks, tin was deposited electrolytically on the steel reducing tin re-

quirements to ½ pound per 100 feet but leaving a coating only .0003 inch thick. The electrolytic coating had to be flowed because the surface was really a succession of steep pinnacles and deep valleys with poor corrosion resistance. Radio frequency heating successfully melted the tin and flowed it evenly on a continuous steel strip moving at the rate of 1000 feet per second. A total of 9600 kilowatts of Westinghouse radio frequency generators—more than twice the wattage of power employed in all radio broadcasting—had been supplied to steel mills for this application at the end of the war.

But the future of this war-born application is even brighter. The steel industry has been having a difficult time supplying the increased demand for tin plating in the post-war era. Since electrolytic plating with radio frequency reflow is a fast process and conserves time, experts estimate that in the next few years 60 per cent of tin plating production will be by this method, with 30 per cent accounted for by the hot-dip process. Currently these production figures are reversed.

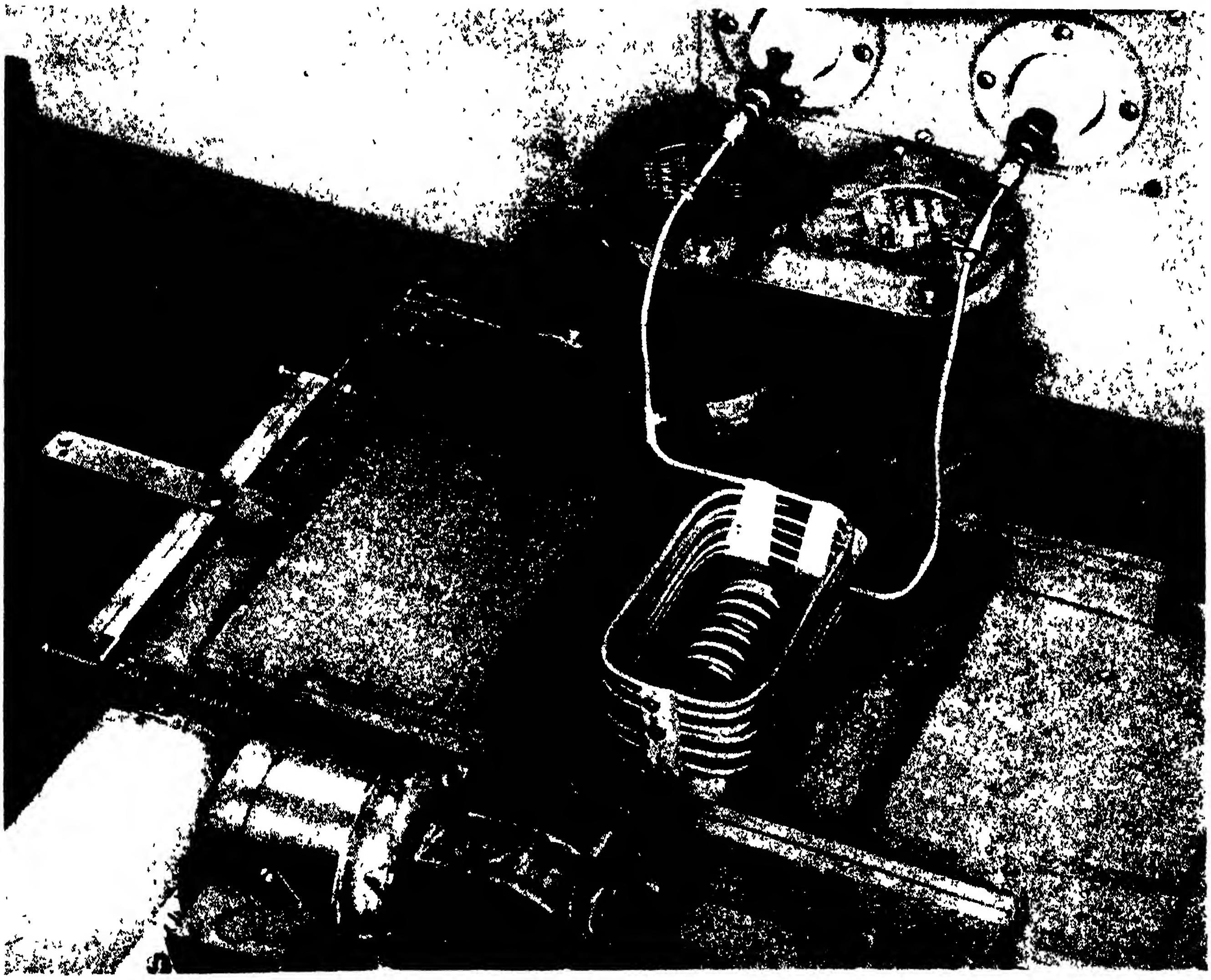
By solving the tin-plating problem successfully, high frequency heating took a long step toward assuring its own future. A decade ago conservative manufacturers looked cautiously at this spectacular process, moved warily where electronics was in use, and under the economic pressure of a receding business cycle were reluctant to discard familiar manufacturing techniques.

How industry's attitude has changed is indicated by a recently completed multi-million dollar plant which is equipped only for the use of high frequency heating to induction-harden gears, shafts and similar machine parts.

Radio or high frequency heating utilizes radio waves similar to those used in short wave broadcasting. In fact, much of the early experimental work was done with regular broadcasting equipment. Two fundamentally distinct methods of applying radio frequency powers are employed: induction, when the workpiece is a material which is a conductor of electricity, and dielectric, when the workpiece is a non-conductor such as rubber, plywood or plastic.

INDUCTION HEATING — Induction heating is based on two familiar and fundamental electrical

Pieces with irregular contours such as the copper-plated coil spring are easily hardened by means of induction heating



phenomena: the principle of induced currents and skin effect. When any electrical conductor is surrounded by a coil carrying an alternating current, corresponding electric currents are induced to flow in the conductor. The induced currents, flowing against the electrical resistance of the conducting material, give off energy in the form of heat, the same type of heat which makes a lamp filament become white hot when current flows through it.

When low frequency alternating current flows through a conductor, or is induced in a workpiece, the current flow is substantially the same at the center of the conductor as at its surface. But as the frequency increases, the current tends to be crowded to the outside of the conductor, so that at a few hundred thousand cycles per second almost all of the current crowds to the surface. This phenomenon is skin effect.

Skin effect is a vitally important characteristic of induction heating because it results in a sharp concentration of heat at the surface of the workpiece Further, since the depth to which the current can penetrate is determined to a degree by the applied voltage frequency, this depth can be controlled precisely.

The advantage of precise depth control is shown in such applications as shaft hardening, where the bearing surface must be made as hard as possible and the core must remain tough and resilient. To solve this problem, the shaft is properly positioned within the inductor coil of a radio frequency heater and current is passed through it. The surface metal then becomes red hot over the desired area so quickly that the heat has no time to wander off where it might do harm instead of good. When the correct hardening temperature is reached, the power is automatically shut off and the hot surface quenched in water or oil Shaft hardening and such operations can also be performed by passing the shaft through a coil at a uniform rate of speed, so that the time of passage through the coil is just enough to allow the shaft's surface to reach the correct hardening temperature. The piece is automatically quenched by sprays of water from nozzles just below the inductor coil.

Contour hardening is another case in which induction heating, with its precise depth control, excels. For example, only a gear's surface is made hard by this process—the unheated core still retains the désired toughness and elasticity. Still another application is the hardening of internal bearing surfaces, almost impossible by any other method but extremely easy with induction heating.

In addition to depth control, induction heating allows precise area control, so that localized hardening or brazing without affecting other brazed joints on the workpiece is a simple matter

OTHER ADVANTAGES — Precise depth and area control are two major advantages of induction heating but there are many others such as:

Increased speed of processing. Heat is generated instantaneously within the material being treated instead of being applied from the outside and then having to soak in by the relatively slow process of conduction. Several pieces can also be treated simultaneously.

Continuous production-line handling. There is no physical contact between the workpiece and the inductor coil which heats it, an ideal arrangement for the use of conveyor systems.

Improved product quality. Surface hardening may be accomplished without affecting the core structure. There is little distortion, minimum scale formation and high uniformity of results.

Economy. Heat may be applied only where it is needed Increased speed of processing cuts labor

Dielectric heating rapidly glues these thick slabs of plywood together. Plates of the press serve as electrodes in this operation

Silver brazing a collar to a tube by induction heating to make part of an X-ray machine assembly. Induction heating is as well suited to such small scale operations as it is to large production-line jobs

costs. There are fewer rejects through better quality control.

Simplicity of operation. Automatic controls reduce the heating application to push button operation. Less experienced operators are required than in other heat-treating processes.

Performance of formerly impossible tasks. A braze may be made a fraction of an inch away from a previous one. Contained gases may be boiled out of electronic tube elements just before final evacuation and sealing. Small, irregular parts may be contour hardened.

DIELECTRIC HEATING — Although it got off to a slower start, dielectric heating is now running a close second to induction heating in the radio frequency field. Although generating equipment is almost the same as for induction heating, frequencies of millions of cycles are generally used. The method of applying this very high frequency power is based on the principle of the capacitor, on the broad principle that any pair of conductors separated by an insulating material constitutes a capacitor.

In dielectric heating, the conductors are a pair of metal plates and the piece to be heated, which must be a material which is normally an insulator, is placed between them. When a rapidly alternating voltage is applied to the electrodes, the molecules in the workpiece tend to vibrate because of the rapid change in polarity of the electrical charges within the molecule. The more rapid the reversal, that is, the higher the frequency, the more rapid is the vibration. This molecular motion produces heat. Since the molecular agitation is uniform throughout the dielectric substance, the heat is also uniform, with no overheating at the surface or underheating at the center.

The amount of heat procured by this molecular vibration is proportional to the frequency since this determines the number of vibrations per unit of time; to the square of the applied voltage since this voltage determines the amplitude of the vibrations; and to the "loss factor" used to express the fact that different materials have naturally different rates of heating. Dielectric heating contrasts with induction heating in that the latter assures precise depth and area control, whereas in the dielectric process heat is distributed uniformly throughout the workpiece. Although the methods of heating the workpiece are diametrically opposed, dielectric heating has literally the same advantages as induction heating.

For example, the use of dielectric heating in the rubber and plastics industry showed increased speed of processing, economy, simpler operation and improved product quality. The thickest plywood that could economically be made formerly was about an inch thick. Dielectric heating makes possible plywoods more than a foot thick, a formerly impossible task, and does the job quicker and cheaper in the bargain.

The application of radio frequency heating to industry's problems are being increased daily, abetted by the standardization of power generators, improved equipment and increased experience. Radio frequency heating in action has shown notable results which have increased demand for further application. However, in common with all production tools, radio frequency heating has limitations and these must be carefully considered before it is put into full-scale application. Radio frequency heating should be used when it is impossible to attain the desired objective any other way, when it can do the job much quicker than any other heating method and when it shows marginal improvement over methods now in use.

NUCLEAR PHOTOGRAPHY

The Photographic Plate Has Become the Smallest Laboratory in the World. One Plate Can Record Thousands of Atomic Disintegrations Over Many Weeks. A Team of English Scientists Pioneers In Using This Method For Study of Cosmic Rays

By A. W. Haslett

THE PHOTOGRAPHIC plate is today the smallest laboratory in the world. Its height from floor to roof—the thickness of the sensitive layer—may be no more than one-fiftieth of a millimeter, and the floor space that of the area of the plate. But within this miniature laboratory many of the most interesting and important of atomic disintegrations are now being produced and recorded. There could be no greater contrast to, shall we say, the Hanford atomic energy plant, or to the giant cyclotrons which physicists use to produce fast-moving projectiles with which to attack the atom. The cost of one method can be reckoned in cents and that of the others in millions of dollars.

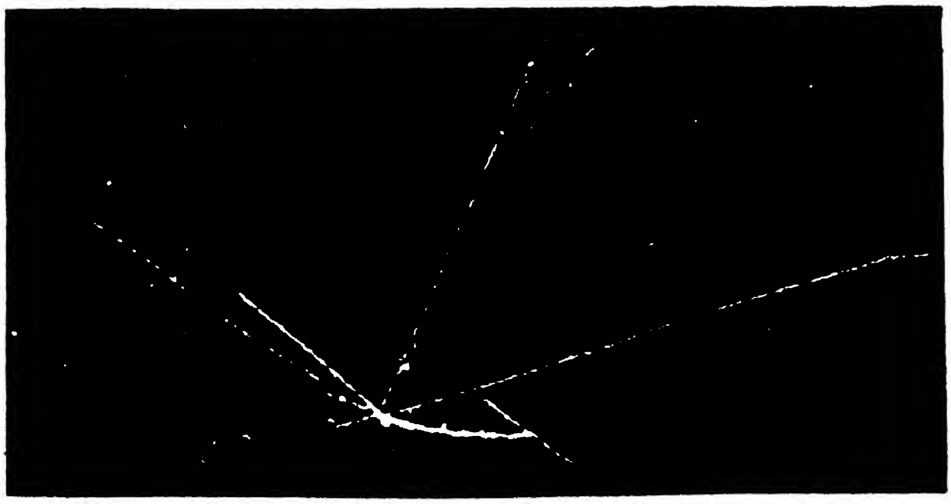
The metaphor that a photographic plate is a laboratory in itself, and not merely a recording instrument, may not immediately be clear. The atomic disintegrations detected by photographic plate, however, are not produced outside the plate and merely recorded. They are produced in the atoms of the sensitive layer of the plate itself.

The fundamental principle of this method is as follows: If an atom disintegrates within the plate, it will produce a number of electrically charged fragments which will scatter from the place where the atom was located Each fragment will have the same effect on the sensitive layer of the plate as would exposure to light. The tracks of all charged particles originating within the plate are thus automatically preserved until the plate is developed. They then appear as so many trails of metallic silver These can either be viewed directly beneath the microscope, or projected on a screen and photographed. They can also be photographed through the microscope.

The scientist mainly responsible for the precision and versatility of the photographic method is Dr C F. Powell of the H. H. Wills Laboratory of the University of Bristol, England. He has been working on it for about 10 years with Dr. G. P. S. Occhialini. In 1934 Occhialini pioneered with Prof. P. M. S. Blackett in early investigations of the positive electron. Occhialini has worked, in the interval, in both Italy and Brazil. To these two scientists must be added the name of the Ilford Company, which has produced the special plates which they use.

MOST IMPORTANT EXPERIMENT — The most important experiment performed by Powell and Occhialini by the photographic method can be outlined by stating that they have obtained automatic records of an estimated total of 3000 individual disintegrations merely by exposing a set of special plates to cosmic radiation for a few weeks at the Pic du Midi Observatory, high in the Pyrenees. All of the disintegrations have not yet been interpreted. A number of spectacular observations, however, have already been made.

A silver atom, for example, has been observed which is shattered into at least 10 or 12 different fragments, probably the most drastic case of disintegration which has yet been seen. Among other new types of disintegration, five examples have been found attributable to the impact of mesons, a particle which is suspected of playing a most essential



The photographic plate records the disintegration of a heavy nucleus by a cosmic ray particle. One fragment (at the bottom of the plate) comes to the end of its range and splits into two alpha particles which fly off in opposite directions

part in holding the nucleus of the atom together.

It should be possible to manufacture mesons in the laboratory when equipment of sufficiently high electrical energy is available. In the meantime, cosmic radiation, which beats down regularly on the earth from outer space, provides the most violent bombardment to which the nucleus of any atom can be exposed. Disintegrations observed by the photographic emulsion technique are in fact a preview of startling disintegrations which will be observed when new high-energy particle accelerators are built.

Until physicists can surpass the natural intensity of cosmic radiation in the laboratory, however, they must make do with what nature provides. It is in the exploitation of cosmic radiation as a weapon in research that the new technique worked out by Powell is most clearly proving its worth.

The possibility of using a photographic plate as a laboratory was recognized by experimental physicists at an early stage in nuclear research. Plates have been used to a limited extent for 15 years. They might even have been adopted as standard equipment if another method using the Wilson cloud chamber had not already been established.

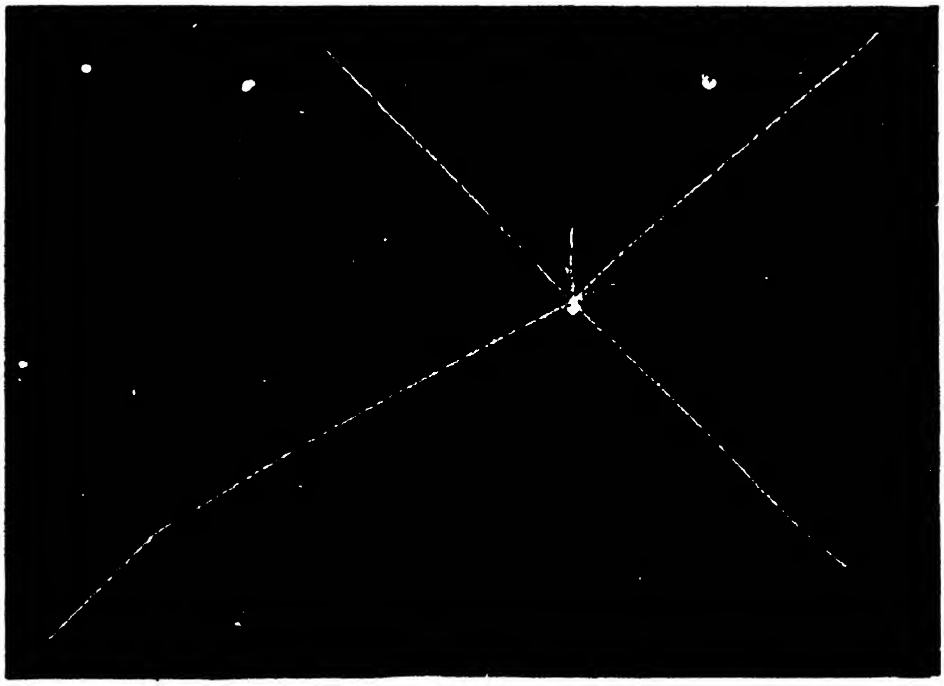
The basis of the cloud chamber method is that the sudden expansion of moist air causes water droplets to collect along the path of any electrically charged particle which passes through the chamber. This makes it possible for the tracks of nuclear particles to be directly observed and photographed, with no uncertainty about the distances they travel. On the other hand, it is necessary that each disintegration or set of tracks in a cloud chamber be separately photographed at the time that it takes place. This means a considerable expenditure in time and control equipment.

EMULSIONS SHRINK -- By contrast, the emulsion of a photographic plate is continuously in action and does its own recording. The principal drawback of the plate method, however, is one which appeared an almost insuperable obstacle to accurate measurement. This is that photographic emulsions shrink very appreciably in processing. In the case of the special plates which are now being used, this shrinkage amounts to as much as 43 per cent. Dr. Powell's greatest achievement, accomplished by long and patient investigation, is that he developed a method of measuring photographic particle tracks accurately in spite of this shrinkage.

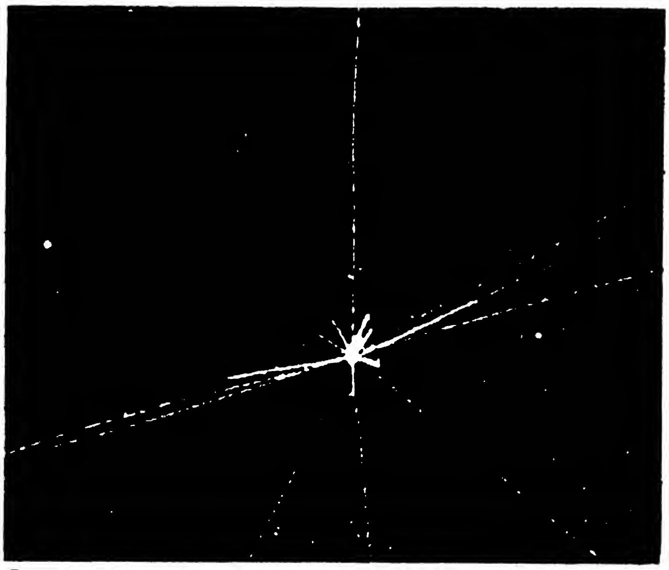
It was necessary, Dr. Powell found, to confirm that the vertical shrinkage of the emulsion was not only uniform over the central area of the plate but was also constant for all plates of the same type. Of equal importance, since the emulsion was a mixed material, was a direct and experimental comparison between the ranges of particles of different types and speeds passing through air and through a photographic emulsion. Finally, since the emulsion is three-dimensional and the tracks recorded might run in any direction, methods had to be devised of accurately determining the "angle of dip" of individual tracks in relation to the glass surface of the plate. Only in this manner could the range of any track be measured.

All of these fundamental requirements had been fully met by 1943. The difficulty remained, however, that the number of grains which were exposed—in the usual photographic sense—by the passage of a particle through the emulsion was not great enough to make interpretation of the plates easy. As early as 1939, Dr. Powell had been in touch with the Ilford Company with the hope of their producing special plates in which the number of sensitive grains would be greater than normal.

The first attempts to develop these plates produced no substantial improvement, and at this point the outbreak of World War II prevented any further work. It was not, in fact, until last year that a series of new plates was made with eight times the usual proportion of silver bromide. It was the development



A disintegration is recorded in which four alpha particles of long range are emitted. The tracks of the four particles lie in nearly the same plane



The disintegration of a heavy nucleus into about 20 fragments by a cosmic ray particle

of these plates, following on Dr. Powell's earlier demonstration of the validity of the method, which led to the recent ferment of research activity.

The activity has by no means been confined to Bristol. By the same methods, learned during a visit to the Bristol laboratory, two Paris physicists were recently able to demonstrate the rare splitting of the uranium nucleus into four separate fragments. Similar plates have also been exposed by workers at London's Imperial College of Science and Technology during high altitude aircraft flights. This, of course, makes it possible to obtain plates subjected to intense cosmic radiation.

Other important points in the use of nuclear emulsions are 1) the types of atoms to which the method can be applied and 2) the scale of the photographic effect. The emulsion of a photographic plate normally contains a number of chemical elements: notably silver and bromine and, among others, carbon, nitrogen and oxygen. If nuclear disintegrations were confined to this comparatively small list, even including a number of other elements present only in trace amounts, the method would be limited in its application. Dr. Powell has accordingly developed methods of introducing into the emulsion almost any other chemical element which he may want for his disintegration experiments.

As to scale, the thickness of the sensitive layer in the special plates now being used is either 40 or 20 thousandths of a millimeter. These, therefore, are the longest distances which any track can be followed in a direction at right angles to the surface of the plate. Since the range of particles in the emulsion runs from 10 thousandths of a millimeter to a full millimeter, many tracks can be followed only when they run parallel to the plate surface.

The photographic record of a nuclear disintegration is thus a star-shaped explosion within the plate with the tracks of the resulting particles scattering in a variety of directions. Some leave the plate before their course is completed and others come to rest within the emulsion so their ranges can be measured. Generally speaking, the kind of particle can be deduced from the appearance of its track. The energy of the particle is calculated from its range.

PROJECTION MICROSCOPE — Dr. Occhialini's chief contribution to the Bristol partnership has been to design and construct an ingenious form of projection microscope. This is of great value in the inspection of exposed plates and in the preparation of photomicrographs. These make possible further study and publication of tracks produced by a nuclear disintegration.

Dr. Occhialini has named his device Telepanto, because it may be used to project an image of the plate on a screen at a comfortable distance. It is capable of automatically scanning the complete area of any plate which is put into it for projection. It also varies its focus periodically, so all sections of the plate may be examined in depth as well as in area.

When it is in operation, this automatic scanning device creates the illusion that individual tracks and "stars" which may have been left weeks before in the plate are alive and moving. Apart from its value in speeding up examination, the same equipment can be used with manual control to photograph the projection screen with the microscope focus at different depths. This is necessary to make composite photographs showing tracks which travel in three dimensions in one flat plane.

As a final result of the photographic method of recording nuclear disintegrations, complete visual evidence for any new type of disintegration can be published so other research workers can readily assess it. With the wealth of material which is still to come, this is an essential requirement if confusion in interpreting entirely new atomic transmutations is to be avoided.

Dr. C. F. Powell—nuclear photographer

LUBRICANTS FOR ELECTRIC MOTORS

Motor Life Is Often Shortened by the Wrong Bearing Greases. Functional Tests for Bearing Greases are Therefore Necessary

By H. A. McConville
Works Laboratory, General Electric Company

THE SERVICE life of an electric motor is inseparably bound to the efficiency of the motor-bearing lubricants. And when the tremendous part played by the electric motor in modern industry is considered, the importance of selecting the proper lubricant for a motor's bearings becomes apparent.

All too often, the selection of such lubricants is managed on a completely haphazard, hit-or-miss basis. Almost inevitably, this results in a long series of prematurely worn bearings and expensive replacements, until the proper lubricant is finally stumbled upon.

The systematic determination of a grease that will satisfactorily lubricate the ball and roller bearings in electric motors under a wide range of operating conditions is by no means an easy matter. It can be simplified somewhat, however, if the least desirable greases can be weeded out by suitable chemical and physical tests made in the laboratory. These tests include measurement of consistency; of the dropping point (the temperature at which the grease will lose its stiffness and drop off a thermometer under standard conditions); of the free acid or alkali content; determination of the kind of soap used to thicken the grease; of the tendency to separate oil; and of the amount of dirt present.

But the final answer of whether the grease will be satisfactory in actual service cannot be foretold by such chemical and physical tests. No two persons will interpret these tests alike. A trial run in a test motor of a size large enough to be representative of the worst conditions that might be encountered in industry is a more satisfactory means of evaluation. By testing the grease in a large bearing operating at high speed over a wide range of temperatures, and observing the condition of the grease at the end of the run, it is possible to predict with reasonable accuracy whether the grease will give the required service.

The motor recommended for such a functional test is a 30 horsepower standard induction motor, operating at about 3600 revolutions per minute, and having roller bearings about five inches in diameter at one end, and ball bearings of the same size at the other. It should have pressure grease fittings for the pressure relief system. The motor need not be loaded.

A 500-hour test on a motor of this size and speed will give the equivalent of a year or more of service. The test conditions should be selected so that the required life of the bearings before failure will be about 10 percent of the service life that can be expected from the bearing.

FIRST CLEAN HOUSINGS — In conducting the test, the bearings and housings should first be cleaned thoroughly with some suitable solvent such as carbon tetrachloride. The bearings should then be filled, using a hand-operated pressure gun. The bottom drain plug should be removed and the bearing filled until excess grease comes out the drain hole. The plug should not be replaced for 30 minutes after the maximum temperature at which the motor is to be run is attained. This procedure prevents a building-up of pressure in the housings due to expansion of the grease, with subsequent overheating. The motor is now run for 500 hours, or for whatever time has been agreed upon, and at the end of the test, the greases in either end of the motor should be carefully examined.

If the lubricant has given satisfactory service, the bearings will not have become unduly noisy; the bearings' surfaces will not show noticeable wear; there will be no gumming of the grease; no free oil will be visible in the bottom of the bearing housings, there will be no metal particles in the grease; and the dropping point of the grease will not have lowered by more than a specified amount. Also, the grease should not get more than a specified amount

harder in consistency, as measured by the A.S.T.M.'s penetrometer, than it was before. And its acidity should not increase more than a figure agreed upon

NEXT A FIELD TRIAL — A grease which meets these requirements is ready to be given a service performance trial in the field in the particular apparatus for which it was intended. It is well to try it out in smaller motors first, and extend it to larger ones later. This field performance is the only true test, as troubles may occur in service which might not have been predicted by any laboratory test.

The test procedure depends somewhat on the test limits set. For ordinary motor applications, a grease should be able to stand about 90 degrees, Centigrade (194 degrees, Fahrenheit), so the temperature on the bearings should be held at that figure. If a grease were to be picked for higher temperature applications, the test temperature could be 100 degrees, Centigrade (212 degrees, Fahrenheit), or even higher.

The speed of 3600 revolutions per minute is again suggested, as many greases will break down in a short time at this speed in the size bearings mentioned, where they may run for months at a speed of 1800 revolutions per minute. These tests, however, will not predict performance in motors operating normally at over 5000 revolutions per minute. A special test motor running at 8000 to 10,000 revolutions per minute is recommended for evaluating greases for these high-speed motors.

It is possible that 500 hours may not be a long enough period, but it should be sufficient for the majority of greases. The test is not planned to run to the final destruction of the bearings, as this is too expensive and time-consuming.

When the grease is examined at the end of the 500-hour period, the term "free oil" does not mean small drops of oil which may be scattered through the grease. But greases that leave a pool of free oil in the bottom of the bearing cup are unsatisfactory. It is believed that the consistency of the grease, measured in tenths of a millimeter, should not be more than 15 points harder than the original unworked consistency at the beginning of the test. The free acid (calculated as oleic acid) should not be over 1.0 percent.

Sometimes, samples of greases submitted for test have been made only on a trial basis in a laboratory, and have not been produced commercially. These may give very good results on the trial run, but the supplier often cannot duplicate them on a large scale. So, if it is known that the grease is only a laboratory sample, a thorough test should be made on the commercial product before giving final approval to the grease.

The greases will not necessarily appear the same in both bearings after the test. The bearing on the pulley end of the motor with the shaft passing through the housing, churns the grease differently from the bearing at the other end, which is enclosed by an end bearing-cap.

Grease in the front end of the motor will usually become much stiffer than that on the pulley end. The best check on changes of consistency of a grease is, therefore, made by testing the hardness of the grease in the front-end housing at the conclusion of the test There are differences of opinion as to how hard a grease can be, and still lubricate the bearing satisfactorily. A suggested range is about 260 to 300 worked consistency, as scaled by the penetrometer.

VALUE OF TEST — What is the value of this kind of test to industry? The type of physical and chemical tests that can be made in the laboratory cannot distinguish uniformly between good and bad greases. Two greases may have exactly the same formula and many of the same physical properties, and yet one may perform well, and the other poorly. No two people interpret laboratory tests alike. So, the obvious answer is to see what the lubricant is like after it has been run in the type of apparatus in which it is to be used. This test is by no means the final solution. But it is an intermediary step between laboratory tests and long-time life tests in apparatus in the field.

Some examples of what can be expected when the described test method is followed will demonstrate its value. All of the greases in the following tests passed the chemical and physical tests without difficulty.

Grease A This ball-bearing grease had a worked consistency of 308 and a dropping point of 332 degrees, Fahrenheit It was run for 18 days in a test motor, during four of which the temperature of the grease in the bearing at the pulley end was 175 degrees, Fahrenheit, and on the front end was 158 degrees By the end of this period, the grease attained a semi-fluid condition, and most of it leaked out along the shaft on the pulley end and into the windings. The grease left in the bearings was very soft and plastered around the balls.

Conclusion. This grease, thinned down too much under the temperature involved, making it quite unsuitable

Grease B. A ball-bearing grease of about 318 worked consistency with a dropping point of 275 degrees, Fahrenheit, was run in the motor at room temperature and performed satisfactorily, as most greases will at such a temperature. Then the running temperature was raised to 175 degrees, Fahrenheit, and held there for a few hours. The bearing temperature rose suddenly to 284 degrees and remained at that point for about two hours, at which time the motor was shut down. The grease did not leak out, but remained very soft in the bearing housings. The same thing happened when the test was repeated.

Conclusion: this grease would not stand 175 degrees, Fahrenheit, without breaking down

Grease C. A ball-bearing grease of 274 worked consistency with a dropping point of 444 degrees. Fahrenheit, this sample was run for three weeks at elevated temperatures—two weeks at 90 degrees, Centigrade, and one at 100 degrees, Centigrade. At the end of that time, judging by its appearance, the grease was in excellent condition and seemed to be operating very satisfactorily When the motor was cooled to room temperature, the grease was quite stiff, but the consistency at operating temperatures was very good, and the bearing surfaces showed a thin film of grease. This grease looked promising, and was chosen for further field trials.

With these results as evidence, it is obvious that such testing techniques can not only result in extending the service of expensive electric motors, but also can go far to reduce delays in production due to bearing failures.

SCIENTIFIC AMERICAN'S
Industrial Digest

COLOR VISION LIMIT

New Estimates Set Human Perception At Over 17,000 Separate Colors

It was recently estimated that wholly unaided eyes can distinguish well over 17,000 separate colors in daylight. Dr. David L MacAdam, specialist in color vision at Kodak Research Laboratories, who reached that figure, bases his estimate on the 17,000 distinct colors of equal brightness that are detectable when observations are made with precise optical instruments To this figure he adds the fact that when large pieces of colored paper are viewed with the naked eye, roughly 50 per cent more colors can be distinguished than by the finest optical means

Under similar conditions some 500 distinct shades of gray—ranging from black to white—can be detected. Dr. MacAdam states that when color is introduced each shade of gray in the middle range of the scale of about 500 shades between black and white is expanded up to 17,000 times. The ultra-fine differences in color studied in the laboratory known as "distinct chromaticities" are the distinguishable features of color when brightness is disregarded.

In arriving at his new figure Dr MacAdam estimates that there are about 250 distinguishable colors in the spectrum, plus 10,000 distinguishable tints of spectral colors and 7000 additional colors such as purple, which do not resemble any spectral colors

TELEVISION OBSERVATION

Remote Viewing of Rocket Test Is Safer, More Satisfactory

Television equipment was used for the first time recently in the testing of high-thrust rocket motors in a demonstration for Army, Navy and other government officials at the proving grounds of the Aero Jet Engineering Corporation. A television camera "watched" the rocket motor tests and sent its report to observers in a conference room where they saw the operations on a viewing screen far removed from the test pits.

It is one of those industrial applications where television should be of tremendous value because it will allow "close-up" study difficult and often impossible to obtain with other methods. Limitations of conventional methods of test viewing are manifold, according to Aero Jet engineers. Observation block houses restrict viewing to either the direct method through laminated safety glass which becomes clouded from close-range effects of propellent fumes, or the indirect method using mirrors which in addition to becoming clouded limit the range of vision and often include distortion Both of these observation systems require apertures through heavy safety walls of the block house thereby weakening the structure They also limit two or three persons per apertures and obviously require the observers to be present within the hazard area of the test pits

The television method has many advantages. The whole operation is viewed from a safe distance, picture light intensity and definition are far superior to direct viewing through glass; and shock-proofed cameras can be mounted adjacent to the rocket unit for viewing intimate details. This close-up view provided by the television camera allows the engineers to detect in time to stop the test firing any evidence of fuel leaks or malfunctioning of the system which could result in an explosion and major damage to the rocket motor and its entire test set-up. Continual observation of the rocket and exhaust flames during the firing period also enables the test engineers to note any irregularities in mixture ratio.

Commenting on this experiment, C. A. Priest of the General Electric Company—supplier of the television equipment—states that this may pioneer installation of similar television equipments in other hazardous industrial work. Most of the television emphasis to date has been placed in the entertainment phase of the industry. However, there are numerous possibilities for

An engineer lines up the television camera to view the rocket test. Sponge rubber pads guard the camera from vibrations caused by the rocket's concussion

industrial application—for example in salvaging ships in underwater exploration, in places where danger exists from possible explosions, fire, dust or fumes; or where remote supervision is necessary as at dams, vehicular and railroad tunnels, for traffic control and so forth—which will be explored as the art develops.

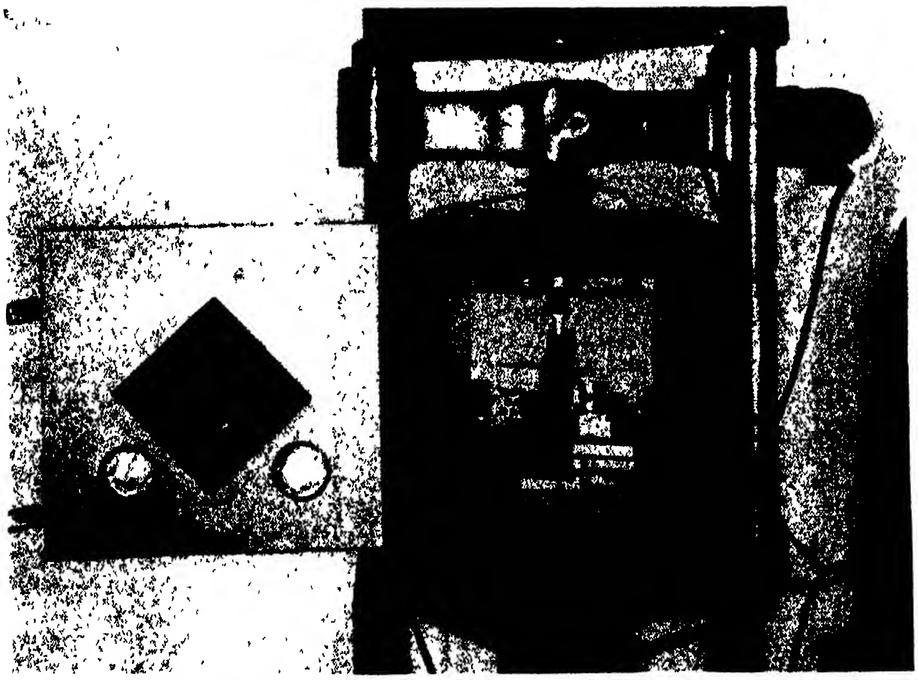
PLASTICS TESTED

In Compression, Tension, Flexure in Temperature-Controlled Cabinet

For determining the physical properties of plastics in tension, compression or flexure over the specification range of temperature of −70 to +170 degrees, Fahrenheit, a new temperature-controlled cabinet has been developed for use on standard Baldwin-Tate-Emery testing machines of 60,000 and 120,000 pounds capacity. The working chamber of the cabinet, approximately 19 inches wide, 18 inches high and 20 inches deep, accommodates Templin type specimen grips of 5000 pounds capacity, a sub-press for compression testing, flexure tool, standard strain followers for either Templin or Microformer type recorders and associated equipment. Standard two-inch gage length tension test specimens, compression specimens two by one half by one half inch, or flexure test specimens up to 16 inches span by two inches wide and two inches thick can be tested in the chamber. The chamber permits a deformation of two inches in the tension and flexure specimens

Behind the working chamber is a servo unit consisting of a dry ice container, a mixing chamber, fan for air circulation, heater coils and electric temperature control equipment.

The cabinet, which is twenty seven by twenty seven by forty inches overall, is constructed by the Baldwin Locomotive Works of polished stainless steel with four inches of thermal insulation. A hinged door and removable top in two sections give access to the interior of the cabinet. Tests can be observed through a double-glazed plate glass window in the door, and two hand holes with insulated sleeves permit manipulation of apparatus in the chamber during tests without opening the door.



The temperature-controlled cabinet mounted for a flexural test

TREATMENT OF WASTE

By Sedimentation Speeded By Slow Stirring

Treatment of a wide variety of industrial wastes may be simplified by a new technique which speeds the settling of sediments and eliminates costly sewer installation, it was reported in a paper presented by A. A. Kalinske and E. G. Kominek of Infilco, Inc., at a meeting of the American Chemical Society.

Although the treatment of wastes varies with the industry, sedimentation, or chemical treatment followed by sedimentation, is employed in most instances, it was explained in the paper, which was read before the Division of Water, Sewage, and Sanitation Chemistry

In many industries, intermittent discharge of high-temperature waste liquid may raise the temperature of the settling waste several degrees in a few minutes, setting up heat currents which interfere with settling, it was pointed out.

Storage in large basins for extended periods of time can offset this difficulty, but storage facilities are not always available and in any event such storage ties up valuable space. The new technique, employing a stirring device for equalizing the temperature throughout the waste liquid and a trap for removing the sediment, permits continuous treatment of waste by sedimentation, it was asserted. The mixing apparatus, called an accelerator, makes use of the strong hydraulic action of a slow moving rotor, thereby preventing settling from taking place on the bottom of the tank. The settling slurry is constantly pumped from a primary mixing and reaction chamber into a secondary chamber where it settles rapidly and is trapped.

FINER CASTINGS

Salt-Free Silica Solution Is Used as Precoat

Solutions which would yield silica particles so fine that the electron microscope alone could measure them long have been the materials for investment precoats which would give precision investment castings their finest smoothnesses. A trouble has been that most of these solutions contained salt which was difficult to remove. Salt-free solutions have finally appeared on the market. Their use is predicted to cause a long stride forward in the precision investment casting art, a stride that will bring the surfaces of castings one step closer to those obtained by machining and grinding.—*E.L.C.*

LEAD-SILICA PIGMENT

Paint Made With One Third The Lead Usually Required

A new pigment which will make three times as much paint from the same amount of lead as is now used will help to conserve the nation's inadequate lead supply and to relieve the current shortage of superior house paints.

The reduction in the amount of lead per gallon of paint is not made at the expense of quality, according to F. J. Williams and A. R. Pitrot of the National Lead Company Research Laboratories. They point out

that by making more effective use of the lead present, paints will have the same long life characteristics now exhibited by ready mixed paints containing equivalent quantities of other lead pigments. Exhaustive paint tests have shown that this pigment is the equal from a performance standpoint of the lead pigments now employed.

One hundred pounds of lead will make 6¾ solid gallons of this pigment compared to 2 1/7 solid gallons of white lead. This will mean over three times as much paint from the same amount of lead.

The function of lead pigments in a paint film is to react with the decomposition products of the vehicle, many of which are acidic in nature, converting them to lead compounds which fortify rather than destroy the film. In the course of this film-saving reaction only the surface of the solid pigment particle is consumed, the rest of the particle remaining to perform its normal function of hiding the surface to which the paint was applied.

Only the surface of the lead pigment particle is effective in imparting long life to a paint film. Therefore a pigment with a minimum amount of lead but with this lead content concentrated on the surface was sought. Such a concept was new, and a pigment particle meeting this description had not previously been prepared.

The new pigment is produced by grinding silica sand in the presence of water to an extremely fine particle size. Lead oxide is then added with a small amount of sulfuric acid to convert part of the lead oxide to lead sulfate This results in an intimate mixture of the ingredients in the water This mixture is dried and heated in a furnace to a dull red heat for several hours under controlled conditions. The resulting product is such that the individual particles are coated with lead silicate and lead sulfate.

This skin or surface layer is firmly adherent to the underlying silica core and is, in fact, an integral part of the grain. The lead silicate and lead sulfate are available for reaction with the decomposition products in paint films, thus serving as if the entire particle were lead silicate and lead sulfate.

SUPER SHOCK-ABSORBER

Mechanism Compensates for Bumps Before They Can Be Felt

A SHOCK-ABSORBER which promises train and bus travelers far smoother, more comfortable rides is now being road-tested. This new mechanism is designed to:

Eliminate more than 60 percent of the bumps and sway caused by irregularities in tracks or roads;

Enable trains to take curves at more than 25 percent greater speeds without so much as splashing your cup of coffee;

Bring about a 4 to 1 over-all improvement in riding ease of trains and buses and permit increased traffic over present rails and highways.

The new system, developed at Westinghouse Research Laboratories under the direction of Dr. Clinton R. Hanna, is the direct offspring of the tank-gun stabilizer which enabled Allied tank gunners to shoot

The bump detector, the brains of the shock absorber, is given a final check

accurately while speeding over rough ground.

"The main difference in the two systems," explains Dr. Hanna, "is that the 'brainwork' in the tank-gun stabilizer was done by a gyroscope, whereas in this vehicle stabilizer it is done jointly by floating weights that feel up-and-down and sideway motion, and a pendulum that senses the pull of centrifugal force and gravity.

"Working together or separately, these two elements can detect and respond to bumps or side-sway in just 0.003 second, thus literally anticipating the movement and correcting for it before it is felt by the train or bus passengers."

The stabilizer automatically moves the car trucks or bus wheels up and down to compensate for bumps in the road surface. Train wheels are moved from side to side to correct for track "weaving." A "tilter" banks the car or bus body as it rounds a curve.

As applied on a railroad car, six hydraulic cylinders and a pair of motor-driven screw-jacks do the "muscular work," Dr. Hanna points out. The cylinders—four for vertical bumps and two for side-sway—are fastened between the wheels and the car body.

"When the car comes to a bump or dip in the tracks," Dr. Hanna says, "the floating weight instantly senses the motion of the body as it begins. This movement opens one valve and closes another, causing oil under high pressure to flow into the proper cylinder. The pumping of oil drives the piston in the cylinder with just enough force in the right direction to counteract the bump and hold the car body virtually motionless. All this takes place in 0 003 second.

"What actually happens is that the wheels are pushed down into the valleys and raised over the peaks of the bumps while the car floats on a cushion of oil in the cylinder. The same type of action moves the wheels right or left to correct for side-sway and the car body moves forward in a straight line."

When the train enters a curve, a similar mechanical brain goes into action, Dr Hanna explains.

"This is a gyro-controlled pendulum which regulates two electrically-driven screw jacks," he states. "The screw jacks are placed at diagonal ends of the car body. When the car enters a curve at a speed not quite right for the bank of the track, centrifugal force swings the pendulum toward the outside of the curve if the speed is too fast, or gravity pulls it toward the inside of the curve if the speed is too slow. In so doing it closes an electrical contact, sending a signal to the electric motors which operate the two jacks These jacks immediately tilt the car body to the correct bank angle."

The tilt mechanism can add up to six degrees of additional bank in either direction within two seconds. So precise is its sense of balance that even when going around a curve at theoretical 40 percent overspeed, the tilter can bank the car to within one degree of perfect equilibrium The permissible speed on curves depends on the design of the locomotive, but even with this limitation the tilter will make possible 25 percent overspeed without passenger discomfort.

Going around a curve even at high speed, the passengers will be able to stroll down the aisles without difficulty. And when the train comes to a standstill on banked curves, the car body will be held perfectly level.

"The big bugaboo of shock-absorber designers always has been the problem of resonance," Dr. Han-

na says. "This means the rhythmic bouncing that occurs when bumps from the road are transmitted through the springs to the car body A succession of one inch bumps may cause the car to bounce from two to four inches; and if this motion were not restrained, the car would continue to bounce higher and higher.

"The best shock absorbers have been able to limit this bouncing to about three inches. The new stabilizer cuts it to less than one inch—an improvement of some 300 percent. Also, by applying all the hydraulic power of the stabilizer to the wheels and helping them move up and down, the traction power of the car is greatly improved."

Although passenger comfort is the chief aim of the stabilizer, improved train and bus schedules should also result from its use, Dr Hanna states, adding:

"Much higher speeds will be possible with comfort. This means stepped-up schedules and a greater flow of traffic over present roads."

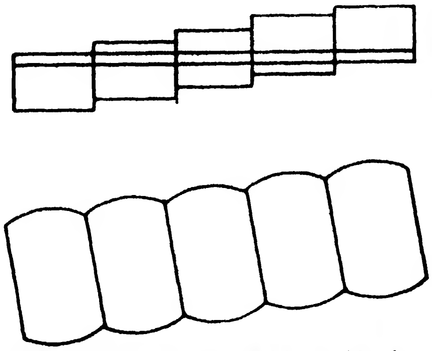
The same equipment used on railroad cars, modified slightly, can be applied to large passenger buses In the case of buses, the system will be simpler due in part to the omission of lateral sway stabilizers Buses have no swing link suspension because they do not have to travel along weaving track.

FASTEST MOTION PICTURE CAMERA

Shutterless Instrument Aids in The Study of High-Speed Phenomena

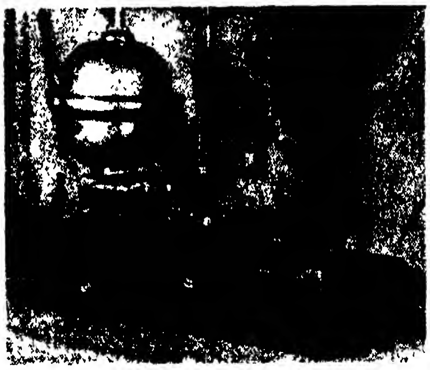
A NEW motion picture camera which achieves the unprecedented speed of 11 million frames per second makes possible such extremely slow motion pictures that a bullet photographed in full flight requires a minute to travel one inch across the screen. This instrument, which was designed by Brian O'Brien and Gordon G. Milne, both of the University of Rochester Institute of Optics, promises to be of great value in the study of many high-speed phenomena.

The revolutionary camera uses no shutter. It achieves its speed through the technique of "image dissection," which consists simply of breaking down the image to be photographed into a series of narrow strips. This dissection is accomplished by a set of small lenses placed side by side in such a manner that a line connecting the centers of the lenses would be slightly inclined from the horizontal. Each lens forms an individual image, with all the images being arranged side by side, descending in step-like order. A metal strip is placed in a truly horizontal position between the lenses and the film so that the images from all the lenses fall upon it. An extremely narrow slit which runs the entire length of the images is cut in this strip and only those portions of the images that fall upon the slit reach the film. The slit passes only the very top of the image from the lens on the lowest level, a small slice just below the top from the next image, and so on, with the very bottom of the image being passed from the highest lens Since all of the lenses view the same event, the light passing through the slit consists of the dissected elements of the original picture joined end to end.



Lenses (below) are arranged side by side, slightly inclined from the horizontal. Images (above) are formed descending in step-like order. Only that part of each image falling on the horizontal slit is passed on to the film

The film is driven past this line of light in a direction perpendicular to the line, at the comparatively high speed of 400 feet per second. This is accomplished by fixing a strip of film to the inside wall of a shallow drum and then rotating it



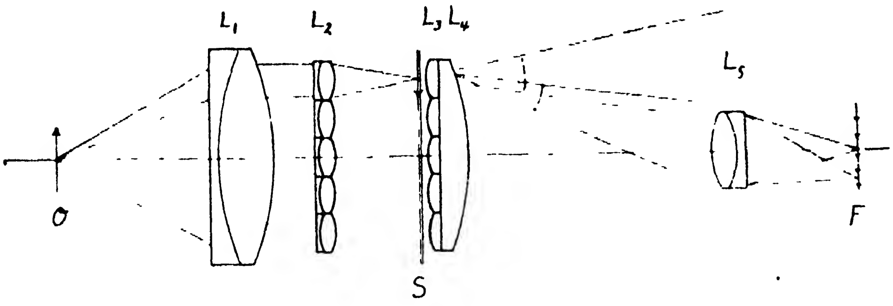
This printer transforms the streak image into a series of rectangular pictures

The narrow line of light from the slit is drawn out into a streak by moving the film, and the variations in photographic density at any place across the film contain all the elements of one complete rectangular picture for the particular instant of the time represented by the position selected along the streak Since the camera is shutterless, the motion of the film naturally produces a blurring of the image. This blurring is limited to the width of the slit which is less than the resolving power of the film itself. Thus the negative need only be moved the width of the narrow slit to produce a complete new frame of the event

The negative is reconstructed into a series of rectangular frames by projecting the film strip back through an optical system similar to the one that produced it. This is done by an automatic printer, which produces an ordinary 16-mm motion picture.

Light source for the camera is a new condenser discharge flash lamp with a flash duration of 1/5000 second. This flash is sufficient to illuminate several minutes of continuous performance on the screen.

The negative is enlarged 10 times in the process of printing back to



Optical system of the image dissector, viewed from above. Light from the event to be photographed (O) is received and collimated by lens (L_1). The multi-lens system (L_2) forms multiple images at horizontal slit (S). Image portions passing through the slit continue through the condensing lenses (L_3L_4) and thence to the final photographic objective lens (L_5). The slit image is formed at the film (F)

a 16-mm motion picture frame Thus the film grain imposes a serious limitation on the quality of the pictures.

The camera is not suitable for ordinary pictures. However, while the esthetic value is missing, the device should be an extremely valuable tool for the study of such high-speed phenomena as explosions, electric discharges, pressure waves and high-velocity jets and rockets.

WHIRL PIT TESTING

Spinning Disks at High Speeds Aids Metallurgical Study

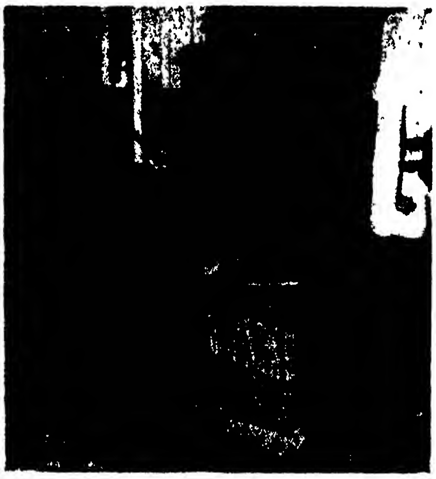
In an armor-plated "whirl pit" 40 inches in diameter and nine feet deep, circular steel plates are rotated at high speeds until they burst. This is one of the most promising of the new testing methods to provide biaxial stress all the way to fracture, according to Mr. W Spraragen, Director of the Welding Research Council of the Engineering Foundation. "It makes it possible to test thicker welded and unwelded plates than is possible by other methods," he states

One of the most valuable uses projected for the rotating disk method will be to test materials and welds at extremes of temperature, and the results should be particularly useful to bridge engineers, shipbuilders, the U. S. Army and Navy and those who use steel at extremely low temperatures.

The project is under the direction of Dr. C. W MacGregor, professor of applied mechanics at Massachusetts Institute of Technology. All tests so far have been pilot tests with the purpose of perfecting the method and equipment. The disks, which can be tested to a thickness of eight inches, are suspended on a flexible steel drive shaft and rotated in a 30-inch vacuum at speeds up to 35,000 revolutions per minute. The vacuum prevents the generating of heat in the plates as they are rotated and makes it possible, by admitting air, to stop the whirling at any given moment.

The whirl pit itself is made of three heavy pieces of class B armor plate, and is lined with lead pigs to preserve the disks for observation and measurement after fracture To date, the disks tested have all been 26 inches in diameter but of different thicknesses. For welding tests a small central disk is welded within the outer disk.

As the disks whirl at high speed. the material actually flows from the center toward the edges and thickens the disks at the perimeter. It is expected that future tests will provide interesting information on plastic flow and on distribution of plastic strains



In this whirl pit circular steel plates are spun at high speed until they burst

The program outlined for the future is as follows·

1 Study of plastic flow and strain distributions on disks 26 inches in diameter rotated to partial yielding and to bursting at room temperature, on welded disks, as-welded and stress relieved, and on unwelded disks annealed and as hot rolled

2 Development of wire strain gage techniques for measurement of brittle fracture conditions at low temperatures, and construction of a refrigeration system for testing disks at low temperature

3 Low temperature studies on disks of same thickness (three quarter to one inch) unwelded, welded, stress-relieved and as-welded

RESILIENT TUMBLING PELLETS

Rubber Slugs Squeeze Into Finest Crevices, Quickly Disentangle

Pellets and slugs for use in tumbling barrels have had the design and materials difficulty that if sharp and pointed enough to get into fine crevices of the tumbled product they tended to entangle and interfere with each other, and if especially shaped to impinge upon special product surface contours they did not always impinge in such positions as to do their work quickly and adequately.

An improvement is found in resilient materials, such as synthetic rubbers, bonded with such abrasives as aluminum oxide. The pellets tend to squeeze into the finest crevices and to follow the most intricate contours, and the resilient release of compression after they have ceased to impinge upon the work surfaces tends to disentangle them and get them out of each other's way. They are resistant to chemicals, therefore may be used in conjunction with solutions which pickle or otherwise improve metallic surfaces while the tumbling proceeds. Therefore tumbling and chemical treating may be done simultaneously.—*E.L.C*

ULTIMATE LENGTH STANDARD

Basis Is Wave Length of Light From Mercury Isotope

The basis for an ultimate standard of length is the length of a single wave of green light radiated by mercury-198, an isotope not found in a pure state in nature, the National Bureau of Standards announced recently. Measurements based on this wave, which is 21 millionths of an inch long, will make possible length determinations precise to one part in 100 million, and the design of new auxiliary equipment is expected to make possible measurements with a precision of one part in one billion. "Such precision in the measurement of length," according to Dr E. V. Condon, Director of the National Bureau of Standards, "has never before been attained by man"

While the meter bar kept in a vault at the Bureau of Standards is the legal length standard in the United States, research laboratories for a number of years have been using light waves for special types of length measurements

The advantages of a light-wave standard over a physical length standard are that it is indestructible and exactly reproducible, and that any laboratory with the necessary auxiliary equipment can have a basic standard on the premises

The primary criterion in selecting a particular light wave as a standard is that it must be as monochromatic as possible (By monochromatic is meant that the red, green or other color used is a single wavelength rather than multiple wavelengths extremely close together.) Up to the present the radiation in the red portion of the spectrum of the element cadmium has been used The cadmium red radiation was adopted provisionally at the 1927 International Conference of Weights and Measures, as a wavelength standard, when 1,553,163.13 wavelengths were defined as equal to one meter

The fundamental advantage of

mercury-198 over cadmium is that it emits a more nearly perfect monochromatic light. Cadmium consists of six principal isotopes that radiate slightly different waves, a phenomenon analogous to receiving six radio stations on nearly the same frequency. Other advantages of mercury are that it does not need special heating equipment as does cadmium and that the human eye is seven times more sensitive to green light than to red. The heating of cadmium "broadens" the red line and limits the degree of precision.

Actual length measurements made with mercury-198 involve the optical technique of interferometry. Two absolutely flat plates made from either optical glass or quartz are placed at the ends of the length to be measured. The plates are partially silvered so that they both reflect and transmit light. When the light energy from mercury-198 strikes the first plate some of it is reflected back (and is therefore of no further significance) and some of it is transmitted to the area between the two plates. This light starts bouncing back and forth between the plates. With each "bounce," some of the light energy is transmitted through the second plate and from there to the viewing and calibrating instruments.

The light energy transmitted through the second plate is seen as a circle at the viewing point so that the end result of a large number of bounces is a series of concentric circles of light. The optical phenomenon that makes measurement possible is the fact that the diameters of the center rings are dependent on the distance between the two plates—or the length of each "bounce." By mathematical calculation the distance between the plates in terms of the length of a single wave of green light from mercury-198 is then determined. Because the unit is so small, and the sharpness of the lines cuts down error due to fuzziness, accuracies heretofore out of reach can be obtained

TELEPHONE CABLE

Aluminum-Polyethylene Sheath Replaces Traditional Lead

TELEPHONE cable sheath using a thin sheet of aluminum covered with a black, rubber-like polyethylene compound, has been developed by the Bell System. The new cable will supplement the familiar lead-covered type which is now at peak production.

Quantity production of the new cable has begun following extensive

Cutaway view of the cable shows outer covering of polyethylene, the thin corrugated aluminum shield and paper binding next to the pairs of wires

tests of its suitability. The cable, called "Alpeth," is to be used within local exchange areas on pole lines and in underground conduit. It will be made in a variety of sizes, ranging from the smaller cables to those containing hundreds of pairs of wires. The immediate purpose to be served by the new cable will be to step up the delivery of cable to the telephone companies and help meet the continuing heavy demand for telephone service

BETA-PROPIOLACTONE

New Organic Material Finds Wide Use in Chemical Industry

A DEVELOPMENT of first magnitude in the field of organic chemistry is seen in the successful completion of research work on a new material known as beta-propiolactone which shows promise of becoming as important to the chemical industry as acetylene or chlorine. The new product is described by Doctors T. L. Gresham and J. E. Jansen, research chemists of The B. F. Goodrich Company, as "another fundamental tool in the complex science of manufacturing organic chemicals. Its use as a basic chemical makes possible for the first time the commercial production of whole series of organic chemicals hitherto regarded as laboratory curiosities." Besides making possible the production of an infinite variety of new chemicals, beta-propiolactone promises to open up new and cheaper reaction methods of producing many basic materials already used in the chemical and plastics industries.

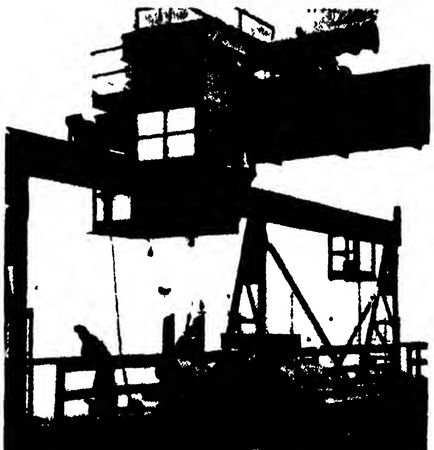
Substances which may be made from the new material range from the liquid used in setting permanent waves to materials used in leather processing. Other fields in which it is expected to contribute either better or more economical products include: compounds for preserving fats and oils; thermosetting resin products which can be made tougher and less brittle; plant-growth initiators and mold-growth inhibitors; essential ingredients for certain man-made rubbers; fungicides; selective weed killers; polymerizable esters for plastic products; intermediates for the paint industry; rubber compounding chemicals and solvents, and "polyblends," in which American rubber and plastics are blended. Manufacture of beta-propiolactone is now being carried out on a small scale at the experimental station of B. F. Goodrich Chemical Company. Fundamentally, the method of manufacture of the substance is through the combination of ketene and formaldehyde. The basic raw materials are coal and water, and ethyl alcohol, the latter derivable from grain, petroleum or coal.

HOPPER UNLOADER

Free-Flowing Materials Are Shaken Out of Railroad Cars

LITTLE more than a foundry shakeout on a grand scale, a vibrating mechanism for use on hopper-bottom railroad cars greatly speeds the unloading of free-flowing materials and reduces the manual labor usually required for such operations. The device literally shakes such materials as coal, coke, ore, slag, lime stone, sand and so forth—frozen or unfrozen—out of the car.

This Car Shakeout is placed astraddle the car to be unloaded by means of a five-ton hoist. When it is put into operation, rythmic harmonics are set up within the machine which are transmitted by contact to the car and to its entire contents. Under repeated impulses the material literally dances away from the sides, and out of the car. Average time for unloading a 50-ton car is reported to be less than



The shakeout in position astraddle a hopper car which is to be unloaded

five minutes, and at times as low as 90 seconds have been recorded. It cleans out a car so rapidly that it is possible to unload an entire train-load without uncoupling the locomotive.

An example of the unloading speed possible with this device is seen in a report from a southern power plant. Formerly a crew of 12 men using sledge hammers worked for 40 minutes to unload a car of pulverized coal. Now, with the shakeout, three men do the job in three to five minutes.

The device operates with no danger to the workmen and without any damage to the car.

MIDGET X-RAY TUBE

Dental Tube Has Hooded Target For Greater Output

No larger than a power tube in a home radio set, a new 70,000-volt dental X-ray tube has operated steadily on test for 1000 hours, the equivalent of two decades of normal usage in a dentist's office. One of the smallest X-ray tubes ever offered commercially, the new design minimizes stray radiation which can blur X-ray film. Key departure in the new design is a copper hood surrounding the tube's tungsten target The X-ray-producing electrons are trapped inside the tube's hooded area, which shields the rest of the tube from bombardment by "backlash" electrons.

Joseph Lempert, the engineer who designed the new tube for the Westinghouse Electric Corporation, explains its mechanism in this manner:

"As the electrons bounce off the target, the resultant X-rays stream through a tiny porthole in the hood, and are beamed onto the film through a window in the glass tube the size of a wrist watch crystal This window, made of special hard glass which transmits X-rays, is ground down to a uniform thickness of about twenty-thousandths of an inch for all tubes, assuring the radiographer of consistent exposures."

Previously, tube windows had to be made thicker as a protection against unused electrical charges unleashed within the tube. As a result, Mr. Lempert added, more than 10 per cent of the useful X-rays were lost. The unused electrical charges in effect jerked gases out of the glass walls of the tube, limiting its useful life.

Another new precaution against unwanted gases is the use of barium as a "getter" which serves as a sponge to absorb gases which might

Small dental X-ray tube is built to operate for 20 years of normal service

remain inside the tube after exhausting and sealing.

The hooded anode was suggested by discovery of such dental tubes among German X-ray equipment seized during the war. The new tube is an improvement on the German design. The hooded anode principle itself had been utilized by Company engineers in 1939 in experimental high voltage X-ray tubes they designed for deep therapy and industrial X-rays.

ACID-RESISTING GLASS

Sandless Material Is Unaffected By Hydrofluoric Acid

Glass which contains no sand resists the vicious, corrosive attack of hydrofluoric acid and uranium hexafluoride—two chemicals that disintegrate ordinary glass Developed by scientists of the American Optical Company, the new product was used in experiments with uranium hexafluoride, the essential chemical utilized to separate the fissionable uranium-235 isotope from the more common uranium-238 in connection with development of the atomic bomb.

The new glass, the first ever known to resist the attack of hydrofluoric acid, is expected to simplify the handling of this important acid which is extensively used in scientific experiments and many important industrial operations, particularly oil refining and synthetic rubber manufacture.

Previously the use of hydrofluoric acid presented difficulties because it could be shipped only in lead or wax containers, Dr. Grosse explained, while in the laboratory it had to be processed in platinum or gold retorts which prevented visual observation of chemical reactions.

To determine the acid-resisting property of the new glass during its development, a piece of it was immersed in a bath of hydrofluoric acid for 50 hours. At the end of that time the glass was substantially transparent, and to the naked eye showed no obvious attack.

At the same time a piece of ordinary glass made of sand, lime and soda was immersed in the acid and within a few hours it was converted into a chalky mass.

To obtain hydrofluoric acid resistance, phosphorous pentoxide, rather than sand, was used as major ingredient of the glass, since that acid instantaneously attacks sand with a disintegrating effect.

RUBBER REINFORCING AGENT

New Latex Increases Strength of Natural, Synthetic Rubbers

A new latex which increases the stiffness, hardness and tear strength of both natural and synthetic rubbers provides valuable reinforcement for the rubber stocks used in such articles as molded toys and sports equipment, fabric coatings, dipped goods and paper impregnates, according to J. A. Weatherford and F. J. Knapp of the chemical products development division of the Goodyear Tire and Rubber Company. Latex compounders have long sought a resin latex which would reinforce the standard rubber latices when incorporated with them This new material called pliolite latex 190 is a highly stable water dispersion of a high styrene-low butadiene copolymer resin and has been developed to perform this function.

In an investigation to determine the effect of incorporating this pliolite latex 190 in natural rubber latex, neoprene latex type 571, GR-S type III latex and chemigum latex type 200 (a Buna N latex), it was found that the new material increased the stiffness, hardness and tear strength of natural rubber latex without appreciably affecting the other properties. It improved the stiffness, tear strength and hardness of both neoprene latex type 571 and chemigum latex type 200. The stiffness, tear strength and hardness of GR-S type III latex were also improved by the addition of this latex.

Since pliolite latex 190 is an effective reinforcing agent for natural and synthetic rubber latices, it can be used generally for increasing the hardness and rigidity of compounds without losing the inherent toughness and resilience of rubber. Its light color and low specific gravity enable it to be used where darker and heavier reinforcing agents cannot be used.

New Products

COOL GRINDING DEVICE

New Cooling Technique Cuts Wheel Heat Several Hundred Degrees

A NEW method of cooling work on any grinder makes possible both the visibility that is possible with dry grinding and finger-tip control over adequate cooling.

The introduction of coolant directly at the point of contact between wheel and work is the principle of "Cool Grinding." It eliminates the need for splash guards, settling tanks, pump motors and hoses, and floor space formerly occupied by coolant units is not needed. All of this represents a considerable saving in equipment cost plus additional savings in coolant oils since only a small amount of coolant is used And the mess associated with the conventional coolant systems is eliminated

The Cool Grinding unit consists of a coolant reservoir mounted on the spindle column, a sight drip valve and a special wheel adapter The coolant is fed from the reservoir at a rate of from one to four drops a second depending upon the material being ground The coolant is directed into the front of the special wheel adapter where it enters the arbor hole of the grinding wheel Since the grinding wheels used in "Cool Grinding" have no lead or ceramic, the coolant enters the wheel at the inside and is thrown by centrifugal force to the outside grinding face of the wheel

In conventional wet grinding the material at the point of contact between wheel and work is raised to a very high temperature and since the coolant is applied not at point of contact but behind the cut the shock of the sudden cooling often results in surface cracks With Cool Grinding the coolant is applied at the actual point of grinding. It is reported that actual tests have shown temperatures to be held several hundred degrees below those found in even the best conventional wet grinding systems. And with Cool Grinding, surface cracks can virtually be eliminated

There are other advantages in using the Cool Grinding system, a development of the DoAll Company. Because the coolant flows through the wheel, it flushes the grinding surface and keeps it clean This results in longer wheel life and better finishes, especially in softer materials such as copper, bronze, aluminum and so on

The cool grinding unit consists of a coolant reservoir, a sight drip valve and a special wheel adapter

PORTABLE ARC WELDER

Submerged Arc Welding Machine Is Designed For Small Operations

COMPACT and portable, a new submerged arc welding machine is particularly useful for making welds that are inaccessible for fully automatic welding, making short welds where it is not worthwhile to mechanize the operation, building up deposits of almost any size or shape and depositing metal to repair weld or casting defects The "Unionmelt" Automatic Flexible Welder as the unit is called, can be used as a primary welding tool in a small welding shop or as a supplementary tool for fully mechanized installations

The special feature of this machine is that the welding nozzle, at the end of a 20-foot flexible hose, when held in the operator's hands, can be moved from one weld to another without stopping to set up track, carriage or other guiding equipment The welding nozzle is claimed to be easy to handle and guide along the seam or over the area to be built up

The flexible hose, connecting the nozzle to the main machine assembly, contains the welding current cable, and two tubes through which the welding rod and the granular material are fed Bare welding rod of any size up to 5/32 inch in diameter in the standard 25-pound coils can be used in the machine.

Granular welding composition is continuously supplied to the welding nozzle by compressed air from a storage tank included on the main machine assembly This tank, holding about 75 pounds of the material, provides an adequate supply so that an entire 25-pound coil of welding rod can be fed without interruption and without danger of flash which might occur frequently if a smaller supply were used. The granular material flows by gravity from the welding nozzle and the operator controls the depth of the layer laid down by the height at which he holds the nozzle above the work surface. Included in the main machine assembly, in addition to the tank holding the supply of granular material, are a specially-adapted standard "Unionmelt" welding head, the control unit and a rod reel. This assembly, compactly arranged, is mounted on wheels and can be moved easily anywhere in the shop. All controls are operated from a small portable switch box which the operator can keep with him within easy reach.

The flexible welder, a product of The Linde Air Products Company, has

The portable welding machine in transit

a capacity of 900 amperes, either direct or alternating current, which may be supplied from any welding generator or transformer. Compressed air at about 35 pounds per square inch pressure is required to force the granulated composition through the flexible tube to the nozzle. Only a small amount of compressed air is used, about 110 cubic feet being required for each tank full of welding composition or for each 25 pounds of rod deposited Simple external connections—compressed air hose, welding cables, and a cable carrying 110-volt current and the contactor and relay operating leads for the control unit—are all that are necessary to make the unit ready for operation

PHOTOELECTRIC CONTROL

Inexpensive Unit Is Versatile And Highly Sensitive

A NEW photoelectric control unit features low cost and versatility. Not only will the unit perform the usual photoelectric switching, controlling and

Control needs no sensitivity adjustment

counting functions, but also it can be adapted for use as a light intensity meter. The device will plug into any standard electrical outlet, and the article to be controlled is plugged into either the normally-on or the normally-off receptacle in the unit's housing.

The internal arrangement of the control unit provides for filters for colored light or infra-red operation. The large (two-inch diameter) light-gathering lens together with the extremely directional optical system (sensitive only to light received from a five-degree arc) makes possible various gaging, controlling and measuring operations with this single unit without the use of a sensitivity adjustment

As an example of the unusual sensitivity of this control, which is called the Electronic Handyman, it will operate in broad daylight on the light of a small flashlight even though the unit be within 10 degrees of facing directly into the sun. The photoelectric control, a product of John T. O'Connor and Company, will continue to operate over a wide range of voltage shifts, and internal taps may be adjusted for entirely different operating voltages The unit is equipped with a self-guarding, self-failing circuit.

PROFILING MACHINE

Ends of Pipes, Bars and Tubes Are Rapidly Machined

PROFILING machines for high-production end-machining operations are designed for turning, boring, burring, chamfering, threading, tapping and so forth on the ends of pipe, tubing, bars and similar pieces These profiling machines, which were announced recently by the Pines Engineering Company, are built for either manual or automatic operation. The automatic types are equipped with hydraulic controls which repeat machining sequence continuously. With the work hydraulically chucked, one or both ends of the work are machined by the action of the rotating heads which hold the cutters and one operator can attend several machines.

Either one or two heads may be employed on these profilers. With two heads, simultaneous machining of both ends of the work is possible, reducing the machining cycle and eliminating the extra handling.

An example of the high rate of production possible with the profilers is seen in the chamfering of both ends of a one-half inch conduit, 10 inches long Here the rate of 800 to 1000 pieces per hour has been reported. And the same machine is said to be used simultaneously to chamfer both ends of screw machine stock at the rate of 700 to 900 pieces per hour.

When desired, profilers may be equipped with conveyors which carry the work to the machine and transport the finished pieces to a convenient point of storage or to where further processing is performed. Such arrangements are fully automatic, eliminating in-process handling, and reducing the possibility of denting or otherwise marring thin-walled stock.

SMALL DEHUMIDIFYER

Unit Dries Gases For Variety Of Industrial Processes

COMPACT and portable, a new dehumidification unit is capable of drying flows of gas or air up to approximately 100 cubic feet per hour and will adsorb about 5500 grains of moisture before reactivation is necessary Suitable for use in a broad industrial field, it has varied applications, such as drying compressed air for lacquer spray guns; drying bottled hydrogen to protect molybdenum heating elements; drying refrigeration coils before

The dehumidifyer can dry up to 500 cubic feet of gas per hour and will absorb up to 5,500 grains of moisture before reactivation becomes necessary

installation and dehumidifying drying cabinets. It is also widely used to supply dry air for testing the results of moisture in air on various products or processes. When materials are to be cooled the unit, manufactured by Lectrodryer Corporation, can be used for supplying an atmosphere which will preclude the possibility of moisture condensation.

With this laboratory model dewpoints as low as minus 60 degrees, and lower, are readily obtained. In actual practice, it is claimed, the unit has dried gases to dewpoints well below minus 76 degrees, C.

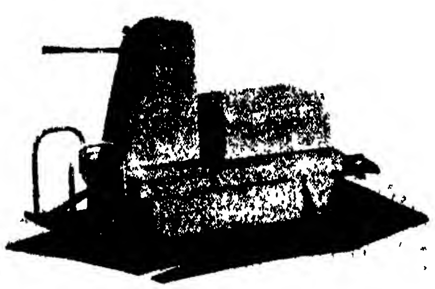
The reactivate the Lectrodryer after it has adsorbed its capacity of moisture it is merely necessary to plug a cord into a 110-volt A.C. or D.C. light socket for two or three hours (the cord and plug are standard equipment). During reactivation a small quantity of air is passed through the dryers and carries off the released moisture.

Although the unit operates on pressures as low as two inches of water, it is built as standard for operation on pressures up to 15 pounds per square inch.

ELECTRIC TOW UNIT

Small Light-Weight Tug Can Pull 10,000 Pounds

LIGHTWEIGHT and inexpensive, a new electric tow unit combines extreme maneuverability and rugged performance with low operating and maintenance cost. Suited for any towing job where maneuverability is a primary factor, the Electric Pony Express Orange Tow Unit, as it is designated, has a turning radius of only 72 inches,



Tow operates on 24- or 32-volt battery

making it possible to turn it into a 62 inch aisle. Moreover, despite the fact that it is capable of hauling 10,000 pounds of trailer loads three to four times faster than walking speed, its remarkably low weight permits its use in elevators, lofts and warehouses whose light construction makes the operation of heavier trucks hazardous Since it is electrically operated, this new truck is fumeless, odorless and silent. These advantages make its use particularly vital in enclosed spaces such as food and drug warehouses where contamination from carbon monoxide gas and employee health and efficiency are important. Furthermore, the absence of oil drip, with the elimination of such resultant hazards as fire and employee-injuries from slipping, tends to establish better insurance and compensation efficiency records.

The operator of this stand-up tow unit can face in either direction, avoiding considerable time loss when approaching and engaging a trailer train and again when maneuvering that train in the opposite direction away from the congested parking area. Wheel base of the tow, manufactured by the Rocky Mountain Steel Products, Inc., is 30 inches; overall dimension, including hitch is 75 inches. The unit is equipped

with either a 24-volt or a 32-volt battery, depending on the speed desired and the draw bar pull required; a speed of six miles per hour can be attained with the 24-volt battery and eight and one-half miles per hour with the 32-volt battery.

ARGON GAS WELDING UNIT

Hard-To-Weld Metals Are Soundly Joined in Inert Atmosphere

A NEW welding machine capable of welding such "hard to weld" metals as aluminum, magnesium, stainless steels, copper alloys, Fernico and Inconel consists of one compact portable unit. Called the Inert-Arc welder, it is designed so that the electric arc occurs in an atmosphere of argon gas. This feature makes it possible to weld the "difficult" metals by cutting down the amount of oxidation of these metals during welding.

Unlike all other methods of welding these metals, inert atmosphere arc welding is unique in being capable of making clean, sound welds, without the use of corrosive fluxes, according to engineers. Many assemblies can be welded in no other way, because of the impossibility of removing the fluxes after welding by other methods, they said.

Another feature of this machine, which is a product of the General Electric Company, is that it does not cause undue radio interference while it is in operation. A pilot spark circuit, which operates for only a fraction of a second during the starting of the arc, eliminates the likelihood of objectionable interference.

HARDNESS TESTER

Rubber and Similar Materials Checked By Simple Gage

MEASURING hardness of rubber and similar materials, a new device combines simplicity of operation with high accuracy and excellent reproducibility of readings. The gage, known as the Rex Hardness Gage, is roughly the size and shape of a fountain pen. It is operated by pressing the indenter at one end of the gage firmly against the surface to be tested for hardness. The indicator of the gage will hold its reading indefinitely, much the same as a clinical thermometer. The instrument, a development of the United States Rubber Company, reads in the same units as the Shore durometer and meets the requirements of the American Society for Testing Materials. The device contains no gears, cams, levers or pivots to get out of order. It is sturdily constructed and, unless it is abused, need never be calibrated.

To obtain a reading the gage's base is pressed firmly against the rubber surface

ROUND BAR MARKER

Stamp Centers and Alines Self on Stocks of Various Diameters

A NEW semi-universal, self-centering and self-alining hand stamp is designed for marking various sizes of solid round bar stock with part numbers, serial numbers, heat treatment data and so on. This round bar marker consists of the holder, a V-block guide, a clamping pin and either individual type or a logotype engraved with the desired lettering. The logotype or individual type fits into the grooved slot of the holder, and the V-guide slips over the holder and marking die. Inserting the clamping pin through the slots of the V-guide and the groove in the logotype completes the assembly of the marker. When the stamp is in use, the V-guide slides up or down, automatically centering and alining the stamp on bars of various diameters.

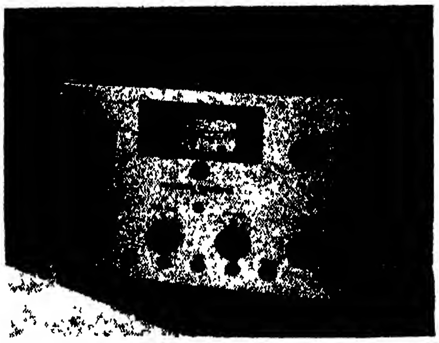
Hand stamp for round stock

This round bar marker, product of New Method Steel Stamps, Inc., is of hardened steel throughout. The handle is knurled and is tempered for long service under severe conditions

SWEEP GENERATOR

Portable Unit Produces All Signals Needed for FM Servicing

A NEW portable sweep generator designed exclusively for servicing and alinement of frequency-modulation equipment, said to be the first unit of this type, furnishes all the signals needed for the complete alinement of frequency modulated radio receivers. It provides a signal tunable over the 88 to 110 megacycle band, unmodulated or amplitude modulated, for the alinement of R.F., mixer and local oscillator circuits.



Frequency modulation sweep generator

For I.F. alinement, the Sweep Generator, produced by the Radio Corporation of America, provides FM signal tunable from 8.3 to 10.8 megacycles, the sweep-width of which can be varied to suit the requirements of wide-band reception. A buffer amplifier between the oscillator and the output eliminates frequency-pulling with changing load. I.F. stages of FM receivers can be alined with the unit, designated model WR-53A, by using the I.F. sweep action of the instrument. Terminals are provided for obtaining deflection voltages for use with an oscilloscope when employing the visual method of adjustment. A phasing control is included to position the scope pattern properly.

The discriminator circuit of an FM receiver can be efficiently adjusted by the visual method by employing the new sweep generator in conjunction with an oscilloscope. The same method can be employed in the alinement of ratio detector circuits. Harmonics of the I.F. sweep unit can be used to check the overall performance of a receiver under dynamic conditions if desired.

The sweep circuit of this unit consists essentially of an electron-coupled oscillator which is frequency modulated by push-pull reactance tube modulators. This provides wide range low distortion FM consistent with excellent center frequency stability. I.F. output from one microvolt to 0.1 volt can be selected by a suitable combination of "step" and "fine" attenuators on the generator. Attenuation to less than one microvolt can be effected with the use of a switch in the output cable. Direct generation of the sweep frequency without the use of "beats" or harmonics, eliminate spurious output signals.

The new test equipment can be externally modulated by phonograph recordings or by a microphone to demonstrate FM operation

COIL CEMENT

Adhesive Strengthens and Preserves Radio Coils

CEMENT to bind together and preserve radio coils and to adhere interior antennas has been developed by the Java

Latex and Chemical Corporation. Called No. 26 Coil Cement, this material is claimed to adhere antenna coils permanently to the inside of radio cabinets, even to cabinets of plastic. The cement can also be used to coat any type of radio coil to render it moisture-proof and to impart greater mechanical stability. The adhesive has very high "Q" and excellent insulating qualities.

PROTECTIVE SURFACING

Self-Healing Coating Guards Metal Structures Exposed to Weather

Designed for long-term protection of storage tanks, bridges and similar metal structures which are exposed to weather, a new self-healing coating material forms a tough but pliable film which effectively seals out vapors, moisture, chemical gases and fumes. The surfacing, called Dum Dum for Metal by its manufacturer, the Arco Company, can be used with a minimum of surface preparation on new or uncoated structures or it may be applied over previously coated surfaces (except those having bituminous coatings). If the outer skin of the protective film is bruised or damaged, the inner portions of the film quickly heal the fault. It is claimed that the surfacing will provide effective protection for ten years or more.

VARIABLE FOCUS MICROSCOPE CONDENSER

Full Illumination in Objectives of Various Focal Lengths Possible

Said to be the first of its kind, a new variable focus condenser for microscopes provides full illumination in objectives having focal lengths of 28mm or more—the intermediate and low-power magnifications The different objectives are brought into position in the customary manner, and by a slight turn of an adjustment knob, the focal length of the condenser is varied to equal that of the objective, providing full illumination. To achieve this illumination in old-style microscopy would require different condensers for each objective.

This new variable focus condenser cannot be fitted to conventional microscopes, but it will be standard equipment on all new Bausch and Lomb laboratory microscopes.

Lowest knob varies condenser's focus

LIQUID LEVEL GAGE

Alnico Magnets Provide Leakproof Coupling of Float to Indicator

Designed to indicate accurately the level of the insulating liquid in transformers, a new liquid level gage utilizes a float inside the transformer tank to transmit the motion of the liquid to a General Electric sintered alnico magnet. This magnet in turn transfers its motion by a powerful magnetic flux to a similar alnico magnet placed on the other side of an aluminum diaphragm and attached to a dial indicator needle.

Two gages equipped with magnetic couplings

The aluminum diaphragm is pressure tight to a minimum of 30 pounds per square inch effecting a permanent seal between the liquid and the gage proper. To effect a seal in the opening where the gage, a product of the Boston Auto Gage Company, is installed, the gage flange is mounted with four studs to the side of the tank, usually below the maximum oil level and is then sealed by a gasket.

METAL ANALYSIS UNIT

Non-Destructive Analysis Made By X-Ray Diffraction

A new Geiger-counter fluorescence analysis unit, which utilizes a new X-ray diffraction technique, is said to make possible rapid quantitative metal analysis. The new unit determines quantitatively the purity of metals or the percentages of alloying components, and quantities of metallic elements dispersed in non-metallic carriers.

Essentially, this fluorescence analysis unit consists of an X-ray generator, a rotating indexing holder for four specimens, a special collimating system, a crystal (calcium fluoride or sodium chloride), a goniometer having a scale graduated from 0 to 90 degrees and a Geiger counter. Crystal and Geiger counter are mounted on and positioned by arms which traverse the goniometer arc.

Complete fluorescence analysis unit

The apparatus serves for determinations on elements ranging from atomic numbers 20 to 41 when a rock salt crystal is employed. For elements 42 to 50, a calcium fluoride crystal may be used.

Use of the apparatus is best explained by discussing a typical problem. Suppose it is necessary to determine the cobalt, nickel and chromium content of an unknown alloy. A specimen of the unknown alloy is placed in the four-unit holder along with standardizing specimens containing known percentages of the alloying elements.

Let us assume that the cobalt content of the unknown alloy is to be determined first. From tables of reflection angles in which settings for various metals are listed, we find that for cobalt the Geiger counter should be set at the 36.8-degree mark on the goniometer scale. Next, the sodium chloride crystal position is adjusted to one-half the Geiger counter angle or 18.4 degrees. By rotating the specimen holder, readings are taken first on one or more of the cobalt standardizing samples and then on the unknown. By comparing the readings and referring to a calibration chart the percentage of cobalt may be determined.

The technique employed with the new Fluorescence Analysis Unit, produced by North American Philips Company, Inc., makes available an entirely new approach to many of industry's problems of metal analysis and control The X-ray method permits analyses to be made without destroying the specimens used for the purpose This method also permits a rapid determination of the percentage of a component present in large or small proportions.

CALKING GUN

Inexpensive Applicator Is Easily Operated

Simplicity of action and low cost are features of a new calking gun produced by the Gibson-Homans Company. This trigger-operated calking gun will accept any spouted calking cartridge. It has no parts to be

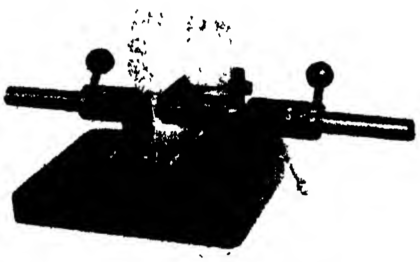
screwed on or off, no gun caps, nozzles, washers or bolts, and it need not be cleaned. Known as the Handicalk, the gun is constructed throughout of steel.

To operate the gun, the base of a cartridge is placed in the metal recess formed as part of the gun's handle. The front end of the gun is then snapped down over the neck of the spout. Thus a firm grip is held over the entire metal shoulder in which the spout is seated. The entire unit weighs less than 14 ounces.

WORK HOLDER

Tool Promotes Safety, Accuracy In Drill Press Operations

Clamping easily on the column of any small standard drill press, a new work holder instantly and firmly secures the work piece with a quarter turn of a single lever. In many instances the tool can substitute for simple drill jigs, thus simplifying tooling and cutting costs. In addition, by replacing makeshift devices such as bolts and C-clamps, the device promotes safety and tends to increase accuracy. The work holder, a product of the Universal Vise and Tool Company, has clamping arms that can be



Holder fits on drill press's column

quickly adjusted along the length of the cross arm to encompass the full width of the drill press table, and they may be swung back to clear a drill jig or machine vise if necessary. Work holders of standard sizes are adaptable to drill presses with columns 1⅝, 2¼, 2¾, 3, 3½, 3¾ or 4 inches in diameter

CARBON MONOXIDE TESTER

Color of Gel Indicates Percentage Of Gas Concentration

Utilizing indicator tubes developed by the National Bureau of Standards, a new instrument is designed to determine the presence of carbon monoxide concentrations in air, and employs the most advanced colorimetric method of carbon monoxide detection. Simple in operation and requiring no special training to use, this carbon monoxide tester is capable of indicating the presence of carbon monoxide from 0.001 to 0.10 per cent by volume in air. The nucleus of the instrument is a detector tube containing a yellow silica gel, impregnated with a complex silico-molybdate compound and catalyzed by means of palladium sulfate. In use, the sealed ends of the tube are broken in the convenient tube-breaker and the tube inserted into the instrument tube-holder. A sample of the air is aspirated through the tube by squeezing the bulb of the instrument

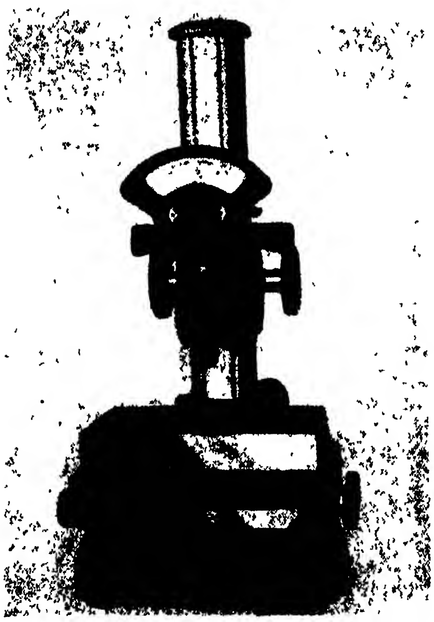
If the air sample contains carbon monoxide when it is drawn through the tube, the yellow indicating chemical turns varying shades of green, directly proportional to the carbon monoxide concentration; the degree of discoloration of the gel is then compared with the instrument's integral revolving color scale for quick and easy reading

The carbon monoxide tester, produced by the Mine Safety Appliances Company, is adaptable to surveys of industrial atmospheres, mine ventilation currents, garages, bus terminals, the interior of aircraft, passenger cars, blast furnace and open hearth operations, public utility mains and conduits, artificial gas plants, and wherever the accurate determination of low concentrations of carbon monoxide is desired.

COMPARATOR GAGE

Interchangeable Tables Enable Wide Range of Applications

Provisions for five interchangeable tables and the use of standard indicators are features of a new comparator developed by the Standard Gage Company. This comparator is suited to a wide range of production and inspection measuring jobs, and it affords a simple and effective means of checking plug gages Any AGD dial indicator of the No 2 or No. 3 size having standard lug-type back can be used. Thus, an indicator having graduations appropriate to the accuracy desired may be mounted on the comparator. Raising, lowering and approximate positioning



Versatile comparator

of the indicator support arm are facilitated by a rack on the rear of the column. Fine adjustment for setting the comparator to a standard is effected by a wing handle. Pressure of the contact point on the work piece can be regulated by means of a knurled bushing and a reed mechanism within the head prevents side thrust from reaching the indicator and thus adversely affecting accuracy.

PIPE CUTTER

Thread Release Permits Fast Adjustment to Work

A new pipe cutter features a push-button release and lock which enables the operator to adjust the tool rapidly for work on any pipe size from one-quarter to two inches. The pull-open-push-close action saves hours of accumulated work-time. This tool, called the Manville-Acme pipe cutter, carries

Quickly adjusted pipe cutter

a unique engagement which locks or rides over a seven-degree undercut buttress thread on the handle. The pins and rollers of the cutter, which is distributed by A. D. McBurney, are of hardened steel. The housing is ruggedly constructed for long life under rough service conditions

HUMIDITY INDICATOR

Built-In Slide Rule Eliminates The Use of Tables

Designed for use in industry and laboratory, a new quick-reading all-metal Humidity Indicator provides readings of relative humidity accurate within ± 1 per cent for general conditions The instrument, product of the Weston Electrical Instrument Corporation, is of wet and dry bulb type, featuring all-metal Weston laboratory thermometers, self-supporting wet-bulb wick covering the thermal element, sturdy all-metal construction and a simplified slide rule calculator giving relative humidity reading directly, thus eliminating the need for tables or psychrometric charts. The unit is light and well balanced, and can be swung if desired to create air movement. The only maintenance necessary is to change the wick occasionally and replenish the water in the reservoir, which is a heavy-walled, large-capacity jar, covered to reduce undue evaporation.

The slide rule calculator, located on the face of the instrument directly beneath the two dial-face thermometers, indicates relative humidity from 10 to

Indicator is accurate to ±1 per cent

100 per cent. With one movement of the slide the proper setting is made according to the readings of the two thermometers, and the per cent humidity is shown immediately on the upper scale. The instrument requires no calibration.

DISTRIBUTION TRANSFORMERS

New Fabricating Techniques Result In Smaller, Lighter Units

DISTRIBUTION transformers, smaller, lighter and more compact than conventional models, have an internal assembly patterned upon time-proved basic electrical design in addition to new light-weight construction techniques made possible by the use of preferred orientation electrical core steel. The new design is said to achieve a 17 to 46 per cent savings in weight with corresponding reduction in size. The transformers are engineered to meet all the recommendations included in the revised second report of the EEI-NEMA Joint Committee on the standardization of distribution transformers from 1½ to 100 kilovolt-amperes, 2,400 through 15,000 volt classes. They represent the latest development in the electrical field as well as the latest advancements in metal fabrication and welding.

Features of the new units include spray Bonderized steel tanks with machine welded seams to insure permanent protection against leaks; high-voltage pockets fabricated from a single piece of special deep-drawing steel permanently welded to the tank wall; recessed tank bottoms to provide additional protection against rusting and mechanical damages in handling; and low-voltage bushings mounted with a gasketed joint which is held in compression by a pressed steel gasket ring. This ring can be easily removed at installation for replacement of low-voltage bushings, if necessary, without opening the transformer.

Other features include standard flat-slotted lugs on internal low-voltage leads which allow quick change from series to parallel or vice versa; the use of preferred orientation electrical steel for efficient core construction; and redesign to reduce copper-to-oil temperature gradients to a minimum, resulting in better short-time over-load characteristics.

The transformers are given three coats of high-quality paint for protection against severe weather conditions, salt and corrosive acid atmosphere.

MICRO-BLASTED FINISH

Presents Smooth Surface Despite Grained Appearance

SMOOTHER than polished metal, long wearing, and highly resistant to scratches is a micro-blasted finish being used on the film sprocket wheels in a sound motion picture projector.

Faced with the problem of obtaining a surface finish on the film driving wheels of the projector that would not mar or scratch the film surface, engineers of Natco, Inc, finally tried micro-

Micro-blasted film sprocket wheel

blasting and obtained the desired results. The finish obtained by this process presents a grained appearance but actually offers less friction and causes less wear on the film than would a polished or plated surface The micro-blasted finish also is more resistant to scratching than are plated surfaces

By micro-blasting the wheels, it was found that all burrs and irregularities were removed

Micro-blasting is similar to the familiar sand-blast treatment but instead of coarse, gritty particles, microscopic particles are hurled by high air pressure against the surface being treated The enormous force of these tiny particles soon removes all burrs and irregularities from the metal and gives an extremely fine grained surface

MASONRY PRESERVATIVE

Water Repellent Moisture-Proofs Concrete, Bricks or Tile

A COLORLESS masonry water repellent that penetrates into cement blocks, tile, brick, concrete, stucco and so forth, gives long-lasting protection against moisture. This material, called Rainchek, will not evaporate or wash away from the treated surface, according to the manufacturer, the Protection Products Manufacturing Company. The material guards against water seepage—the direct result of normal moisture in the ground working its way through the basement walls and through basement floors. It protects outside walls from becoming discolored due to ground moisture or rain saturation, and helps prevent masonry disintegration that comes from moisture accumulation and freezing under the surface.

The passage of moisture through masonry usually leaves a deposit of alkaline salts on the surface causing large white stains. This "efflorescence," as the stains are called, is effectively controlled by Rainchek, the manufacturer reports

SHEET METAL NOTCHER

Precision Shearing Without The Use of Dies

STURDILY constructed, a new flexible precision shearing unit will cut notches rapidly and accurately in sheet materials, thereby eliminating dies for this specialized application A 90-degree notch of any size within the capacity of this "Notcher" can be cut in one operation either at the corner or in any position along the edge of a sheet It is also possible to shear angles both smaller and greater than 90 degrees, and many straight shearing operations can be performed with this convenient unit

A flexible gaging arrangement built into the Notcher allows a notch of any

Notcher makes a clean, burr-free cut

dimensions desired to be exactly located, providing precision in all duplicated parts. The cam of this tool is equipped with roller bearings, and the shearing pressure is distributed evenly on both shear blades. A clean cut free from rough edges and burrs is assured

The cutting range of this Di-Acro Notcher, a product of O'Neil-Irwin Manufacturing Company, extends from the lightest plastics, fibers, mica, leather and rubber to heavy gages of aluminum, cobalt steel, chrome molybdenum, leaded brass and stainless steel. The material capacity is 16 gage steel plate, and the greatest possible 90-degree notch is six by six inches

CURRENT BULLETIN BRIEFS

Conducted by K. M. CANAVAN

(The Editor will appreciate it if you will mention Scientific American when writing for any of the publications listed below)

HEAT FOR METALS is a 32-page ready-reference booklet which includes information on the latest developments in heating equipment for steel mills; history of the development of gas chemistry and heat treatment; prepared gas atmospheres and heating equipment applications to processing such as gas carburizing, carbon restoration, atmosphere hardening, gas normalizing and annealing, gas cyaniding, gas quenching, gas malleableizing and atmosphere heating for forging. *Surface Combustion Corporation, Technical News Bureau, Toledo 1, Ohio.—Gratis. Request this booklet on your business letterhead.*

GRINDING WHEEL DRESSERS. This 18-page booklet describes the Carboloy line of diamond impregnated cemented carbide grinding wheel dressers. Because of the use of a number of small diamonds securely held together in a matrix of hard carbide metal, it is claimed that a less expensive dresser gives faster and more accurate truing. Three standard nib sizes are available from stock. Request Booklet DR-480. *Carboloy, Inc., Detroit 32, Michigan.—Gratis.*

SHADOGRAPH SCALES is a four-page brochure describing and illustrating six types of scales which feature the substitution of light projection indication for mechanical reading. Specifications, capacities and sensitivities are given for each model. *The Exact Weight Scale Company, Columbus 12, Ohio.—Gratis.*

THE GUIDEBOOK TO RIFLE MARKSMANSHIP. This 48-page booklet, prepared by The National Rifle Association of America, was originally prepared as a course of pre-induction training for men about to enter the armed service. Presenting an authoritative series of fundamental lessons in the use of small arms, whether .22 or large caliber, this booklet is now aimed at promoting the popularity of this all-year-round sport. *O. F. Mossberg and Sons, Inc., 131 St. John Street, P. O. Box 1302, New Haven 5, Connecticut.—Gratis.*

CUTTING FLUIDS FOR BETTER MACHINING. Completely revised, this 72-page pocket-size catalog contains data on the application of oils for cutting, grinding, drawing, quenching and tempering, and all other phases of metalworking and industrial lubrication. In addition, useful sections on metal cutting mechanisms, the selection of cutting fluids, rules for prolonging tool life, handy tables of standard steel specifications, independent research committee data and marking system chart for grinding wheels are included. *D. A. Stuart Oil Company, 2729-39 South Troy Street, Chicago 23, Illinois.—Gratis.*

PLASTILE PLASTIC FLOORING. A laminated vinyl floor tile is described in this four-page folder. Available in 20 color combinations, this plastic flooring can be layed with ordinary linoleum cement. *The United States Stoneware Company, Akron 9, Ohio.—Gratis.*

M.S.A. PORTABLE WELDING FUME EXHAUSTER is a two-page bulletin describing how this exhauster can be used where stationary ventilating systems are unavailable or impractical, or where operations are performed in cramped quarters, or where the welder must move from place to place in enclosed areas. Request Bulletin CU-1. *Mine Safety Appliances Company, Braddock, Thomas, and Meade Streets, Pittsburgh 8, Pennsylvania.—Gratis.*

ROTARY KILNS. This 32-page bulletin describes and illustrates rotary kilns for cement, lime and chemical plants. Special construction features of this company's kilns and associated equipment are included. Request Bulletin 07B6368. *Allis-Chalmers Manufacturing Company, Milwaukee 1, Wisconsin.—Gratis.*

BROADCAST OPERATOR'S HANDBOOK. In 288 pages this handbook presents facts that can serve as a general set of rules for good operating practice. This handbook is divided into these six parts: Operating in the Control Room and Studio; Operating the Master Control; Operating Outside the Studio; Operating the Transmitter; We're Off the Air; and Technically Speaking. *John F. Rider Publisher, Inc., 404 Fourth Avenue, New York 16, New York.—$3.30.*

PRINTED CIRCUIT TECHNIQUES, by Drs. Cledo Brunetti and R. W. Curtis, is a 43-page booklet based on performance and application details as well as precautions and limitations. A section on comparative performance of printed circuit elements is included, as well as a bibliography covering processes, patents, applications and other relevant matters. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.—25 cents.*

BALL BEARING OVERHEAD CONVEYOR TROLLEY. Sub-titled "An engineered trolley for overhead conveyors, simple and rugged in design," this eight-page folder describes this trolley equipment which can be used on this company's own conveyors or purchased separately. This folder gives dimensions, weights, trolley ratihgs, allowable chain pulls, list prices and other data. Request Folder 2241. *Link-Belt Company, 2410 West 18th Street, Chicago 8, Illinois.—Gratis.*

Books

THE BOOK DEPARTMENT of Scientific American is conducted, with the co-operation of the Editors, to make available for you a comprehensive book service. Each month the Editors select and review in these columns new books in a wide range of scientific and technical fields. In addition, they are ready at all times to advise you regarding the best available books on any subject. You are invited to use this service freely. Tell our Book Department what kind of books you want and you will be furnished with the names of available books, including prices. When inquiring about books, please be specific; remember that we can be of the greatest help only when you tell us just what you are looking for. Books listed in these columns may be ordered from our Book Department. Add 25 cents per book for mailing outside U. S. All remittances are to be made in U. S. funds. Prices given are subject to change without notice.

ASTRONOMY—REVISED EDITION

By Skilling and Richardson

FROM the several extant treatises on elementary, non-mathematical, descriptive astronomy the editors, since its first publication in 1939, have usually selected this one to recommend to lone wolf readers because it is written in a more direct, homespun style of approach than others. Now it has been revised and enlarged by 113 pages plus four azure sky charts. Comparison of the two editions reveals no mere nominal revision but much entire rewriting. Facilitating this, the text has been re-set. It is up to date as of 1947, July 6, and it still is the editor's selection for the lone wolf reader. It gives a well-rounded coverage of the modern science of astronomy. Authors are professional astronomers, one as a teacher, the other at the Mt. Wilson Observatory. (692 pages, 5½ by 8¼ inches, 309 illustrations, 4 charts.—$4.85 postpaid.—*A.G.I.*

MECHANICAL DRAWING

By Fred Nicholson

THIS excellent text on mechanical drawing is the result of the author's (the head of the Academic Division of the Henry Ford Trade School) twenty years of experience in this field. The subject matter is presented in logical sequence, and the methods of teaching and the problems for practice are designed to bring the drafting room of industry into the high school classroom. With this book the transition from one to the other should not be difficult. (211 pages, 7½ by 10 inches, profusely illustrated.)—$2.10 postpaid.—*N.H.U.*

EXPERIMENTAL CASTING PLASTICS

By Thomas A. Dickinson

A FINE presentation of the results of important research. The book is devoted to formulas and simple new methods of making rigid or flexible patterns, molds and casts—from plastics or for use with plastics. The processes are simple and economical enough to be used in any workshop, large or small, and the data should be of equal value to the home craftsman and the factory engineer. While it comprises only 32 pages, it is set in small and closely-spaced type and provides a wealth of ideas. Sources of materials and equipment are given for the convenience of those who would like to experiment further. (32 pages.) —$2.10 postpaid.—*A.K.*

POWDER METALLURGY

By H. H. Hausner

THE MINDS in industry that are about the hardest to shunt toward new knowledge are those of metallurgists and their employers. This phenomenon of resistance to the new doubtless explains the laggardness of powder metallurgy. So far there has been in this field some pragmatic technology, but little science. Dr. Hausner (Rutgers research associate) briefly, too briefly, describes the technology, and makes a stark attempt to advance the science. He found that the American Society for Metals has finally compiled a glossary of 90-odd powder-metal terms, which he reproduces. In hope, presumably, of stimulating theoretical thinking in behalf of this growing fraction of metals industries he gives over a full half of this book to bibliography. (307 pages, 5¾ by 8¾ inches, graphs and tables.)—$7.10 postpaid.—*M.W.*

PRINCIPLES OF MICROPALEONTOLOGY

By Martin F. Glaessner

DURING the past few years the petroleum industry has become increasingly conscious of the importance of micropaleontology. And with this increasing realization has come a proportional increase in the demand for trained micropaleontologists. One of chief obstacles in the training of these specialists, however, has been the lack of adequate texts on the subject. This book, written by the chief paleontologist for the Australasian Petroleum Company, is designed to fill this need. Part I of this book reviews the main types of microfossils and the methods applied to their study. Part II is devoted to a discussion of the fossil representatives of the foraminifera. Part III deals with the historical se-

quence of microfaunas, the methods used in their detailed stratigraphic analysis and examples of the application of microfaunal studies to problems of economic geology. (296 pages, 6 by 10 inches, illustrated.)—$6.10 postpaid.—*N.H.U.*

THE YEARS AFTER 50

By Wingate M. Johnson, M.D.

Sound, solid, sane, sensible, safe advice for oldsters, covering, chapter by chapter, bugaboos; blood pressure; lung troubles; heart ills; digestive ills; dietary fads; rheumatism and arthritis; glands; mental changes; exercise and recreation; preparing for old age and dying. The author is a long-experienced practicing doctor. His book represents modern majority medical opinion without leanings toward the radical. Much of it is reassuring, tending to diminish apprehensions. It is not a home medication book, beyond the fact that good advice is home medication. (153 pages, 5½ by 8 inches, unillustrated.)—$2.10 postpaid.—*A.G.I.*

MODERN DEVELOPMENT OF CHEMOTHERAPHY

By E. Havinga, H. W. Julius, H. Veldstra, and K. C. Winkler

The researches described in the present paper-bound volume have to do with the development of the sulfonamides as it has progressed in Dutch laboratories tackling problems arising in this connection from several different points of view. A brief concluding chapter relates to Dutch investigations of antibiotic substances that might be isolated from the products of metabolism of micro-organisms. (175 pages, 5¾ by 8 inches.)—$3.60 postpaid.—*D.H.K.*

STEEL CASTINGS

By Eric N. Simons

Although based on British practice, this book is so clearly and simply written that American users of steel castings will overlook minor discrepancies. Because of the non-technical style of presentation, the text will appeal to students, beginners, users of steel castings, salesmen, and so on, who need an overall knowledge of the raw materials, methods of production, testing procedures, and the like. (208 pages, 5 by 8 inches, well illustrated.)—$5.10 postpaid.—*A.P.P.*

PICTORIAL CONTINUITY

By Arthur L. Gaskill and David A. Englander

Subtitled "How to Shoot a Movie Story," this book presents the vital fundamental principles of camera continuity. In plain and simple language it tells the amateur cameraman how to make a coherent motion picture with even the most modest equipment. Both Gaskill, a former newsreel cameraman

and wartime head of the School Division of the Signal Corps Photographic Division, and Englander, newspaper man who served as a combat photographic officer during the war, are highly qualified to write on this subject, and their book should be of great value and interest to the vast army of home movie addicts. (149 pages, 5½ by 8 inches, illustrated.)—$3.10 postpaid. —*N.H.U.*

SEQUENTIAL ANALYSIS

By Abraham Wald

In the large scale production of manufacturers and in the gross behaviors of populations it is practically impossible to scrutinize each piece or person. Random sampling becomes necessary. It can supply satisfactory statistical inferences. One efficient method of reaching such inference, and decision, is sequential analysis. Its characteristic feature is that the number of sampling observations need not be determined in advance. A particular method of sequential analysis, which Professor Wald (of Columbia University) devised to facilitate the production of good wartime materiel, is the sequential probability ratio test. This test, he asserts, "frequently results in a saving of about 50 per cent in the number of observations over the most efficient test procedures based on a fixed number of observations." Higher mathematics is useful in reaching the statistical inferences most efficiently, but is not necessary for understanding this significant new statistical technique. (212 pages, 6 by 9¼ inches.)—$4.10 postpaid.—*M.W.*

SUNSPOTS IN ACTION

By Harlan True Stetson

Coinciding with the maximum of the 11.2-year sunspot cycle this book brings up to date a round-up of our knowledge of a fascinating corner of science. Sunspots and radio; sunspots, earth's magnetism and northern lights; radio and the moon; radio, solar eclipses and cosmic effects; sunspots their nature, origin and prediction; effects on weather, life, and the economic cycle; cosmic terrestrial research—these are the main subjects discussed with their numerous appertaining theories in this work, mainly one of pure science, in which the author, long a master science expositor and leading researcher in this special field, instead of skipping technicalities, explains them in plain language as he writes. (252 pages, 5½ by 8¼ inches, 50 illustrations.)—$3.60 postpaid.—*A.G.I.*

THE FUTURE OF TELEVISION Revised Edition

By Orrin E. Dunlap, Jr.

Some of the past, present and future problems of television are here discussed, along with this industry's possible impact on the home, the theater, on music, news, sports, radio and so forth. Revisions in this new edition

bring it abreast of recent changes in the field, and include extensive additions to the historical appendix, a chronological listing of the steps in the advance of television. An interesting, if often over-enthusiastic book. (194 pages, 5½ by 8½ inches, illustrated.)—$3.10 postpaid.—*N.H.U.*

FOOD PRODUCTS

By Saul Blumenthal

A book full of practical, factory-tested formulas for making hundreds of commercial food products. Includes special chapters on dehydration, freezing, food plant sanitation, and the compositions of foods. Written for the canning, flavoring, beverage, confectionery, essence, condiment, dairy, meat, fish, and allied industries. This book wastes no words; it is intended to be understood and acted upon. (986 pages, 6 by 9 inches, unillustrated.)—$12.15 postpaid.—*E.L.C.*

WHEN THE EARTH QUAKES

By James B. Macelwane, S.J.

Earthquakes, their causes, kinds and field study; sea quakes and the waves they cause; seismographic; seismographic instruments in wide variety; interpretation of seismograms; earthquake engineering; microseisms—these and other aspects of earthquake science are treated in a popular yet far from superficial manner in this book by a noted scientist. Its reader would have a right to feel himself as well informed on earthquake science as is possible short of study of the really abstruse mathematical treatises. (288 pages, 6 by 9 inches, 251 illustrations.)—$5.10 postpaid.—*A.G.I.*

THE SAILING SHIP

By Romola and R. C. Anderson

Six thousand years of history of the sailing ship, dealing with the evolution of hull and rig types through Phoenecian, Greek, Roman, Viking, medieval, 16th and 17th Century and modern periods. A most satisfying characteristic of this little book is this: The text discusses the exact illustrations chosen, instead of illustrations more or less relevant—often less—being hunted up and dragged in by the ears to brighten up a text already written. This doubles the value to the reader and shows conscientious preparation. (212 pages, 5½ by 8 inches, 134 illustrations.) — $3.60 postpaid.—*A.G.I.*

Because of increased production costs of books, publishers' retail prices today are subject to constant change. It may be necessary, therefore, for our Book Department to advise book purchasers of increased costs, even when orders sent are based on current quotations. ***The Editor***

BEGINNER'S TELESCOPE

Needn't be a Crude One Nor Its Maker a Genius

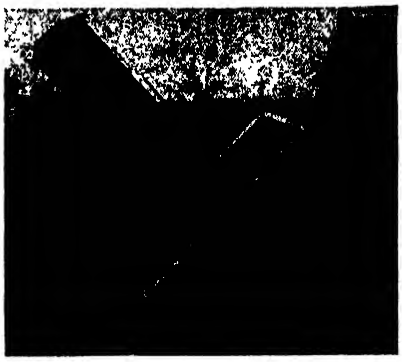
Amateurs who make their own telescopes go about it approximately thus:

They get a prepared kit of materials and make the main optical part, the concave mirror, first. They buy an eyepiece and prism and mount these three in a home-made mechanism of which the one shown is typical. Made mainly of wood, it suffers in no way for that, costs little, requires only average skill to build and is both artistically and mechanically attractive.

First thing the interested reader asks, and naturally, is: "What about that concave mirror? For that scares me a little, as I've been reading how it took the experts 11 years to finish the big one in California." That one did, since the genius increases as the cube of the diameter, but a 6" one—can you tinker an alarm clock?

The mirror-making kit contains a 6" glass blank and another of same diameter to grind the first one against; abrasive grains for the grinding; pitch and rouge for the polishing. You push one disk over the other by half-hour spells during a dozen spare evenings.

This sounds stupid and monotonous. It would be but for the leavening, for there is a simple testing set-up that measures millionths of an inch with light rays and this constant testing is



Typical homemade telescope

the leavening: throughout, you watch exactly what you are accomplishing. Thus you don't need to wait till the end to detect your mistakes but can catch them as they develop and improvise stratagems. Some claim they get as much fun out of the mirror making as out of the telescope later.

Next, you send the completed mirror away to be coated with aluminum in a vacuum—for silvering is obsolescent. Then you make a mounting.

The mounting shown was made by Theodore Van Abbema, Chicago, is very simple, efficient, inexpensive. He kept track: $24.50. Did he count his time? Do folks count their time playing bridge? It is a fact—some say a scandal—that many builders don't half use their telescopes. Too busy making more of them. Bigger ones and different, specialized types.

Telescoptics

A Monthly Department for the Amateur Telescope Maker

Conducted by ALBERT G. INGALLS

Editor of the Scientific American books "Amateur Telescope Making" and "Amateur Telescope Making—Advanced"

UNCOMMON optical grinding and polishing materials such as boron carbide, sapphire dust, titanium oxide, diamond dust, together with uncommon facts about some common abrasives, are the subject of a systematic survey by John M. Holeman, 305 Thayer Drive, Richland, Wash. He writes:

Today, many other substances than glass are being optically worked. To name a few: metals, especially hard ones that do not tarnish; crystals; transparent salts and plastics, each of which seems to be best worked with some particular combination of abrasives and laps.

There is a trend toward harder and harder abrasives because they lessen the time of working and thereby lower the cost of the finished product. The makers of diamond tools advertise:

A high precision Blanchard lens generator. Used for shaping lenses

"Diamond is the cheapest abrasive you can use." In many cases this turns out to be true. A dollar's worth of diamond will remove more glass than a dollar's worth of any other abrasive, and with the expenditure of less effort.

The arbitrary Mohs scale of hardness used by mineralogists is very deceptive. Diamond on this scale is 10, sapphire 9, topaz 8, quartz 7, feldspar 6, apatite 5, fluorite 4 and so on. These indicate the relative hardness of the minerals but not their abrasive power and not the breadth of the steps in hardness between the various degrees. One might be led to believe that each degree of hardness represented by a number meant a uniform increase in hardness and abrasive durability. Experience shows that this is far from true. Actually, the steps from fluorite 4 to feldspar 6 are very close but from topaz 8 to diamond 10 much greater. The hardness numbers do not reveal this disparity.

In the discussions that follow there will be no attempt at completeness nor will all the means of using any particular abrasive be indicated. The information offered represents the experience of only one amateur.

Sand: This, the cheapest abrasive to buy, is still used where nothing else is available or where cost is paramount. Plate glass is ground flat with sand. During the War when better abrasives were under priority some amateurs used sand. PNs stranded on Pacific islands used sand. Pure sand is quartz and has a hardness of 7. This is greater than that of glass, which varies from 5½ for soft crowns to 6 for hard flints. Sand may be crushed, sieved, washed and levigated and has been used to produce excellent work on both metal and glass. In the form of a sand blast it is the quickest means of removing glass, and blown through suitable rubber stencils it can be used for chanelling glass tools and will perform glass removing operations that would be very difficult by any other means.

Crushed steel: This inexpensive byproduct of the steel mills (see "A.T.M.") is available only in coarse sizes, but is useful for bringing a large piece of glass to shape. It cuts Pyrex readily.

Emery: A form of corundum (not Carborundum) which came originally from natural sources, but in this country practically all of it that is used as an abrasive is manufactured, permitting better control of the purity and uniformity. Chemically, emery is the same as sapphire, both being aluminum oxide, and has a hardness of 9.

Emery is available in all grades from very coarse to extremely fine and in some countries is used in the coarse sizes almost to the exclusion of silicon carbide, Carbo, for example. It is generally believed that the pits and scratches left by emery are different from those left by Carbo and are easier to polish out. Consequently emery is almost universally used as a final abrasive. Similarly, because it seems to chip sharp edges less, it is often used for the fine grinding stages of roof prisms and other sharp-edged elements, this being a case where the fastest abrasive is not always the best.

Manufactured emery is a clean white powder easy to refine and levigate. In many plants used emery is saved, washed, and re-levigated to produce finer grades. The best description of this process, which is more or less applicable to refining all abrasives, is found in Dévé's "Optical Workshop Principles."

Silicon Carbide: Chemically, Carborundum, usually shortened to "Carbo," and Crystolon, are silicon carbide and have a hardness greater than 9. In coarse grades, at least, these remove

glass much faster than the same grade of emery—which, as we have seen, is only a fraction of a hardness degree less hard. Silicon carbide is today available in grades from very coarse to 600 grit. No. 1000 Carbo, used in wartime, has been discontinued. The price, like that of any abrasive, varies with the fineness and is less per pound than fine grades which are more difficult to produce. In any case, it is considered an extremely cheap, hard abrasive. Silicon carbide is used to cut quartz and metals as well as glass and, in the form of inexpensive resin- or rubber-bonded thin disks, is used to saw glass and other materials.

Boron Carbide: Sold as "Norbide," this has hardness 9½ and is therefore much harder than silicon carbide; it is

Cutter: diamonds in sintered metal

the hardest material known excepting the diamond. Commercially it is available in at least two grades, 100 and 400 grit, from the Norton Co., Worcester, Mass., and it represents the ultimate in loose abrasives at present. Though it is only a fraction of a hardness degree higher than silicon carbide and emery, it breaks down much less rapidly and can be used to rough out a 6" Pyrex mirror in half an hour when properly applied. This material is also useful to charge biscuit cutters and wire saws for cutting glass and harder substances.

In 1947 boron carbide cost 50 times as much as silicon carbide, but the price will probably decrease. In appearance it resembles silicon carbide, being black and yet crystalline, but when broken down and wet it forms a dirty black slurry that is much more difficult to clean up than other abrasives. Metal tools that have become embedded with it are difficult to clean and will continue to scratch for a long time due to the difficulty of breaking down the very hard grains. This is one worker's experience. Another says almost the opposite. Because boron carbide grains are blocky in shape they will not charge metal tools as readily as do the sharper abrasives; in fact, when it is actually desired to cause a metal tool to take and hold a charge of it, cast iron having plenty of voids should be selected. [The Bill of Rights of the United States Constitution guarantees the freedom of workers who may wish to choose sides in this little dispute, and an account of their findings will be welcome.—*Ed.*]

Sapphire Dust: This is a by-product of the artificial sapphire industry which during the war made millions of jewel bearings for instruments. Sapphire crystals are grown to large size, then sawed up to make bearings, all the sawings

becoming waste. The Linde Air Products Company, East Chicago, Indiana, has several grades at surprisingly low prices. A half pound of No. A5175 "Polishing Powder" cost $5 in 1946. It has a grain size comparable to very fine emery. Though chemically it is the same as emery and, like it, has a hardness of 9, it is a very different abrasive. It cuts and polishes glass, Pyrex, quartz, sapphire, and metals more readily and to a higher polish. Used on glass laps it will put the sharpest possible edge on microtome and other knife blades. Used on hard laps it grinds and polishes (though not optically) stainless steel, Stellite, and many other difficult metals. Used on pitch or felt it polishes quartz and harder materials in a fraction of the usual time, though for best finish a final treatment with rouge should be added. This snow white powder is clean to handle and, of course, can be levigated like emery or diluted with talc to reduce its cutting speed.

Diamond: During the war greatly improved techniques for using diamond were developed. Previously, rotary diamond saws were made by rolling or pressing diamond chips into slots or nicks in the edge of a copper disk. Such saws cut well until they snagged a sharp edge and the diamonds were dislodged and lost. Further, the soft copper blade was so flexible that it was difficult to make an oblique cut and the saw wandered off on a crooked path. Most postwar saws are made of steel with the diamonds brazed on, so that it is practically impossible to remove them Such saws last almost indefinitely. A 10" blade costs about $6. They will cut glass, quartz, rocks, firebrick, hardened steel or any hard substance. In a recent demonstration with portable equipment, an 8" thick concrete highway was thus sawed in two in 30 minutes at much less cost than the job could have been done with air hammers.

Another development of the diamond saw is the hole saw or biscuit cutter used for making large holes in glass and other hard materials. Such hole cutters are now available so cheaply that it hardly pays to make one. They cut faster, cooler and with less danger of chipping than the usual cutter charged with loose abrasives. When they are properly operated the hole produced has a beautiful finish with only extremely fine chips on the exit side, and the removed plug looks as if it had been turned and fine ground.

A recent development is a diamond boring tool made by Felkin Tool Company, Torrance, Calif., which forces lubricant (usually water) under its cutting edge through a stationary water connection on its rotating shank. Such a saw cuts ten times as fast as the familiar diamond hole saw and I have seen an operator cut sixty 1" diameter holes in thick glass in less than two hours.

Besides saws and hole saws, diamond milling cutters and lathe tools are available. The former are metal cylinders with the surface covered with brazed-on diamond chips. They can be used either on a milling machine or a surface grinder. It is amazing to see such a

cutter smoothing off the top of a line of glass prism pressings on power feed at the rate of several feet a minute. Diamond lathe tools can be used to turn glass disks round or to shape lenses. The deep curve of a Schmidt mirror, for example, can be quickly cut out with such a tool. In fact, if diamond cutters are used, it is possible to work glass very much like metal and on the same machine tools.

Probably the most advanced development of this kind is the lens generator which makes precision lenses from glass blanks without the use of laps or loose abrasive. The blank is clamped in a holder and a diamond cutter adjusted by a graduated wheel runs over the surface at the desired curvature. The resulting lens is of good quality and even has a fair polish. A simple adjustment of the dial allows a different radius to be cut.

Diamond drills for small holes consist of a single properly shaped diamond fastened to the end of a steel shaft. Such drills are mass produced in the size, about 0.05" diameter, that is used for drilling mounting holes in spectacle lenses, and can be made to order in other sizes. The selection of the stone, with the mounting and shaping of the point, are a job for the expert and may be considered reasonable at $35 for the size described. Small holes can be drilled in hard materials, using a vibrating hardened steel wire and diamond dust, by a process that is exactly the same as star drilling in concrete. The National Bureau of Standards, Washington, D. C., has recently developed some very superior chemical and electrical methods for drilling extremely small holes in diamonds which would probably be applicable to other hard materials also.

Diamond is too expensive to use loose like silicon carbide and emery. Instead, a tool or lap is made and charged with diamond powder or chips. Lapidaries, in smoothing and polishing gems, spread a small amount of diamond dust in oil vehicle on a smooth soft iron or copper lap; then, with the lap rotating at low speed, they press down on the surface with a small hardened roller, which forces the abrasive into the soft metal. The cutting action of such a charged lap is a combination of grinding and polishing. It is like grinding, in that relatively large particles of abrasive are used and consequently there is rapid removal of material, and it is like polishing, in that the abrasive particles are fixed in a comparatively soft lap and are not free to roll. The result is that a diamond lap cuts rapidly but leaves a semipolished surface covered with scratches caused by the larger particles. The spaces between the scratches are pretty well polished and this is very convenient in working glass, as the surface always has a good enough finish to give a reflection for test purposes.

Next month, more about diamond abrasives; how to make diamond laps; data on titanium oxide; and Barnesite, its composition, how it should be applied, where it may be obtained. Also garnet fines as a finishing "emery."

ON THE COVER: Elemental phosphorus in the process of manufacture. For the story of phosphorus see page 101.

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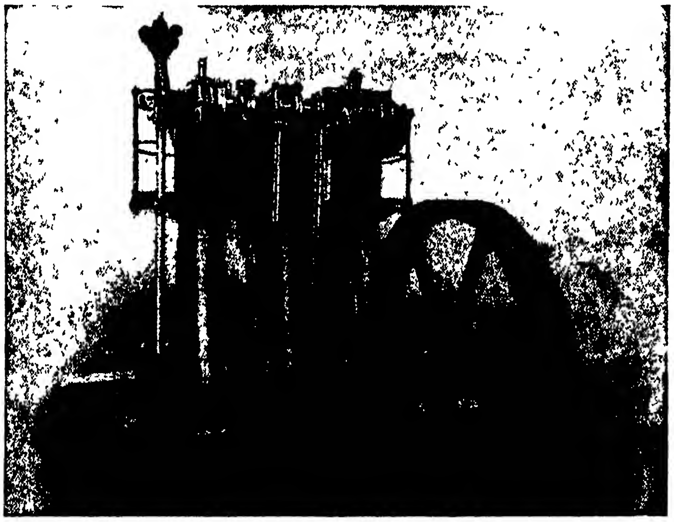
J Years Ago in . . .

(Condensed from Issues of March, 1898)

KLONDIKE AND CALIFORNIA — The expected rush to the Klondike is already well under way, and judging from the present indications, it is probable that the army of fortune-hunters which will enter this inhospitable region during the coming season will far exceed in numbers the emigration to California in the days of forty-nine. To those who foresee the disappointment which is, of necessity, in store for the majority of these people, it would be a consolation to be assured that the Klondike exceeds the California gold fields in richness. Unfortunately there is no evidence that it does. It is probable that not one in a hundred of the California miners found the fortune or even a hint of the fortune for which he set out. The proportion is likely to be even smaller in Alaska.

DIESEL'S HEAT MOTOR — An improvement, marking an advance as important in its way as that of the internal combustion motors over those using external combustion, has been made by Mr. Rudolph Diesel, of Munich. The experiments which led to the construction of the present successful machine, which is known by the name of the inventor, began in 1882, and the conditions which govern the machine were fully formulated in 1893. In the ordinary



forms of gas or oil engine the charge is ignited by a jet, hot tube or electric spark and the combustion is so rapid as to be practically explosive. In the Diesel motor the igniting spark or jet is dispensed with altogether, and the temperature of ignition is secured by the compression of pure air.

MAINE DISASTER — As we go to press the mystery which envelops the "Maine" disaster is as great as ever and the country is still anxiously awaiting the verdict of the Court of Inquiry. So faithful have the members of the board, the survivors of the "Maine," and the divers who are at work on the wreck been to the policy of silence which has been enjoined by the administration, that practically nothing of an authoritative or expert character regarding either the cause of the wreck or its present condition has been made public. Meanwhile, both the administration and Congress have been taking all necessary steps to place the country in a state of full preparedness for such complications as might follow upon the publication of the Court of Inquiry's report, if it should prove that the "Maine" was blown up by design.

A MUSICAL WHEEL — The bicycle has reached another phase of its constant development through a novel and highly interesting invention, consisting in a musical instrument which may be attached to any bicycle and plays popular airs, without the aid of the rider, in a loud and melodious manner, when the machine is in motion. This instrument constitutes an entertaining companion for the bicyclist on his roamings, which are frequently rather lonely; it is so much more welcome as it will be a companion entirely submissive to the rider's wishes.

100 Years Ago in . . .

(Condensed from Issues of March, 1848)

A NEWLY INVENTED RAIL — The whole of the line of railway between Darlington and York in England is being relaid with new rails, chains and sleepers. The rail is of new invention, and of a very superior make, and is considered as a great improvement upon the old description, as the surface of the rail being convex, it presents much less surface to the wheel, and thereby the friction is much reduced—a great desideratum.

COAL TRADE — The average freight of coal from Philadelphia to Boston in 1847, was $2.75 per ton. In 1848 it will be $1.75, making a difference in favor of the buyer of one dollar per ton. Besides the inland freight to Philadelphia, will be reduced perhaps an average of 25 cts. or more, and some reduction must be expected in our rates here. Altogether we expect to put coal into Boston, at not far from $5 per ton of 2,240 pounds, for the opening; and we trust our eastern friends with that assurance, will not have to look abroad for supplies.

DEAFNESS — M. Bonnafont, of Paris, a military surgeon, gave an account at the January session of the Academy of Sciences, of a method employed by him in cases of deafness, to ascertain whether the nerve of sound has lost all its susceptibility. He has ascertained that the skull is a good conductor of vibration, and that, if it be struck by vibrating objects, the nerve of the ear is acted upon whenever its susceptibility has not been entirely destroyed.

KNITTING BY STEAM — A number of influential inhabitants of Ipswich, England, have introduced into that town an important branch of industry, likely to give employment to a large number of persons. Machines are now at work knitting stockings by steam. The work is done with beautiful accuracy. One young person can attend to three machines, and each machine will knit one stocking in three hours.

IMAGE OF THE SUN — M. Becquerel has announced to the Academy of Sciences, at Paris, that he has ascertained that the image of the sun with its colors may be obtained on a plate of silver properly prepared. The preparation consists in submitting cautiously the plate to the action of chlorine. A fine photographic image of the sun, in which the orange, yellow, green, and blue are distinctly marked, is then obtained.

AN ANNOUNCEMENT TO OUR READERS

The editorial function of the Scientific American, as it is stated on the cover of this and other issues, is the reporting of "progress in industry." This is one of the last issues of the Scientific American which will be published under this policy. In May the Scientific American will become an entirely new magazine.

The Scientific American will no longer restrict itself to reporting progress in industry. It will cover all of science: the physical, biological and social sciences, as well as their more significant applications in medicine and engineering. The new Scientific American will be designed for an audience of intelligent laymen. Among these are the scientists themselves, the medical men and engineers, the executives and managers of industry and those engaged in such non-technical professions as teaching and the law.

It has already been announced on this page that the new Scientific American would be founded on a unique collaboration between the scientists and a new board of editors. Since then some of our readers, knowing who the scientists are, have sensibly asked: "Who are the editors?" The Board of Editors of the new Scientific American, together with some pertinent biographical data, is presented herewith:

The Board of Editors

The editor and publisher of the new Scientific American is Gerard Piel, 33. Piel's principal professional experience has been as science editor of the national magazine *Life* and as assistant to the industrialist Henry J. Kaiser. As indicated by his title, Piel will devote some of his time to the business problems of the new Scientific American, but he will also be the head of its editorial staff.

Managing editor of the new magazine is Dennis Flanagan, 28. Like Piel, Flanagan has received most of his professional experience as science editor of *Life*. Under Piel, Flanagan will coordinate the various editorial functions of the Scientific American.

Another member of the Board of Editors is Leon Svirsky, 43. Svirsky has worked as a reporter for the New York *World* and the New York *World-Telegram* and successively as education, science and medicine editor of the weekly news magazine *Time*. Svirsky is also editor of the current study of the U. S. daily press entitled *Your Newspaper*.

Overseeing the graphic arts in the new Scientific American is K. Chester, 29. Chester has been variously an artist, an art director and a photographer, the latter for *Life* and other national magazines. Immediately after the war Chester was Chief Photographer for the International Tribunal at Nuremberg.

The fifth member of the Board of Editors is Albert G. Ingalls, 60. Ingalls, as any long-term reader of the Scientific American knows, has been a member of the staff of this magazine since 1923. In recent years his principal contribution to its pages has been *Telescoptics*, the monthly column known to all amateur astronomers. In the new Scientific American, Ingalls will continue to write his column and will also assist with other editorial duties.

The Work of the Board

The work of the Board of Editors has been discussed in previous announcements. It begins with the common conviction of the editors that the men who are best qualified to write about science are scientists. Since scientists, however, must devote most of their time to science, the editors must undertake a large part of the job of communication between the scientist and the intelligent layman.

The work of the editors is naturally synonymous with the aims of the new Scientific American. It will primarily create a magazine which communicates scientific information to the intelligent layman in a language which is neither technical nor patronizing. In accomplishing this, the new Scientific American will fill a large gap between the scientific and technical press on the one hand and the general newspapers and magazines on the other. And in bridging this gap it will also contribute to the diffusion of information among the compartmentalized specialties of science. But the highest aim of the new Scientific American will be to present scientific knowledge to the end that science shall occupy the same place in the mind of every thinking citizen that it occupies as an integral part of our modern civilization.

A technician running a fractional distillation of a phosphorus compound. Through such analysis the purity and uniformity of the product is maintained

Scientific American
MARCH • 1948

PHOSPHORUS: BEARER OF LIGHT AND LIFE

First Isolated Three Centuries Ago, It Is a Key Constituent Of Life's Perpetual Cycle. The First of Two Articles

By William Mann

IN A CERTAIN sense, phosphorus served to introduce mankind to modern chemistry. It was the first chemical element to be discovered by a single man bent on research. As happens with most new elements, the usual controversy about the priority of this discovery arose, and in the 17th Century there were several claimants for the honor. But an impartial study made in our own time of authentic letters written by the disputants nearly three centuries ago, confirms the claims of a certain Hennig Brandt of Hamburg, Germany. It seems clear that in the year 1669 this "uncouth physician who knew not a word of Latin" (one of the numerous sneers published about him by more educated and jealous opponents) was the first human being on this planet to see the impressive glow of elementary phosphorus.

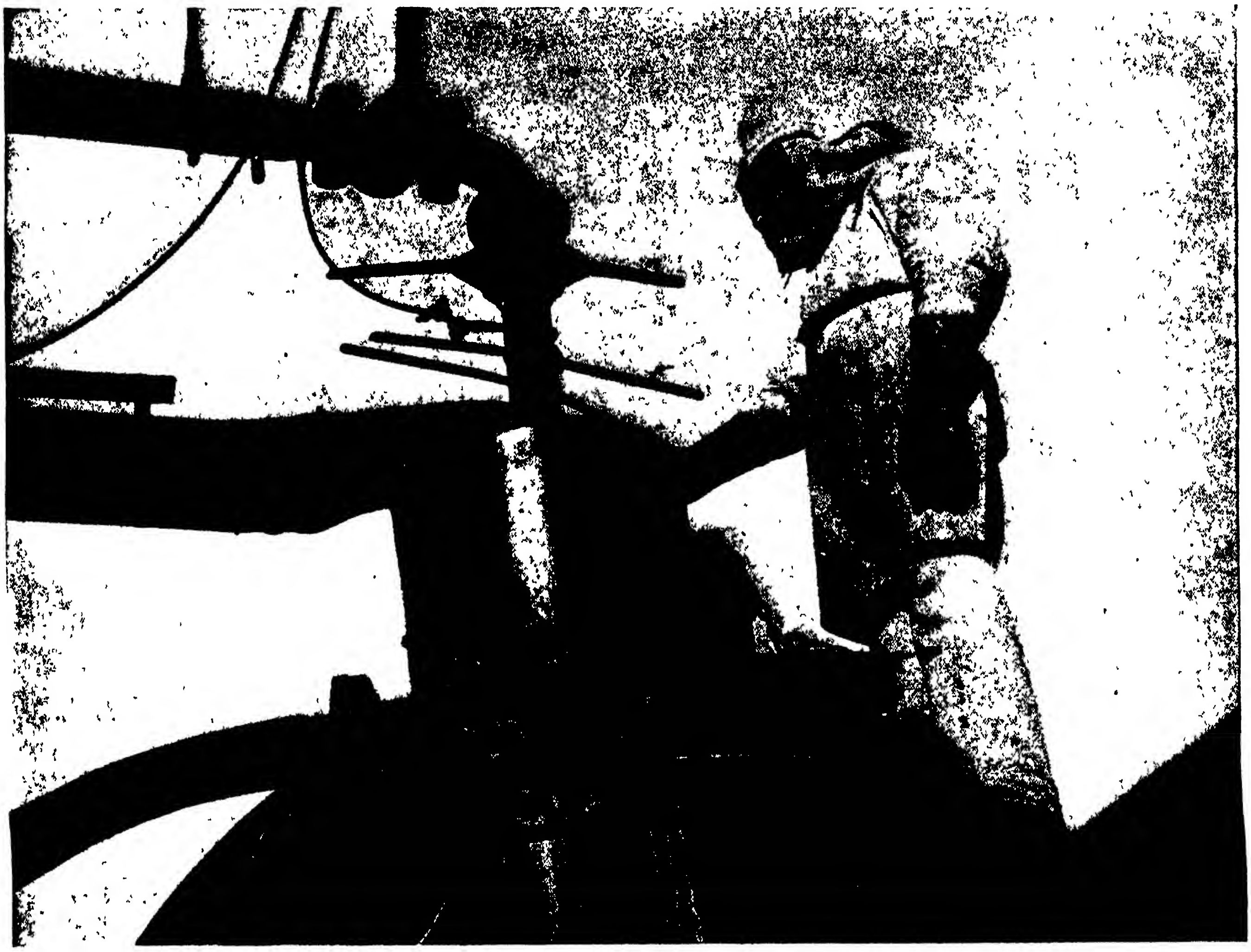
There are older elements, of course. Six that are found native or are easily reduced from their ores—silver, gold, iron, copper, lead and tin—are even mentioned in the older parts of the Bible. And certain others, such as carbon and sulfur, have been known and used from time immemorial. The prehistoric discoverers of all these are lost in the dim corridors of time. But phosphorus is not found native, and is difficult to reduce from its compounds. Its discovery was therefore a pioneer achievement of great importance. Without proper furnace equipment phosphorus would be difficult to prepare today.

PHOSPHORUS IN THE LABORATORY — These facts are reflected in present-day analytical practice. Phosphorus is found in a host of products, and the modern analyst is often called upon to determine it; but none of the recommended procedures call for a direct determination of elementary phosphorus. Generally speaking, the more reactive an element is, the harder it is to handle, and the practical analytical chemist therefore would rather not see his phosphorus in the active elementary state. It is much easier to work with this element indirectly and in stable combinations. The chemist prefers to titrate the nice yellow compound of hydrated ammonium phosphomolybdate, which is very easy to make and to keep. Also, it has a molecular weight of 1931, which is enormous for an inorganic compound. The practical advantage of this unusually large molecule is that if any of it is lost in transfer less than one-sixtieth part of the loss is phosphorus. But this huge molecule makes a very bulky precipitate, and for the higher percentages of phosphorus the chemist prefers to weigh ignited magnesium pyrophosphate, which is slightly more than a quarter phosphorus.

When Hennig Brandt first produced elementary phosphorus, he was amazed at what he saw. It turned out to be a white and rather soft and waxy substance, and even when cold it glowed in the dark. Of course, he was not looking for such a new substance at the time. Like most alchemists, he was looking for an older shining yellow element. He was in fact trying to make gold out of human urine, or trying to use urine for the conversion of silver into gold. In short, he had set for himself a research objective of considerable difficulty and the mere discovery of a new uncoinable element was probably something of a scientific disappointment to him.

Nevertheless, Brandt swallowed his disappointment and proceeded to live for the rest of his life by exhibiting his strange offspring in dark rooms, and by advertising its allegedly valuable medicinal properties. Occasionally he sold a small sample of it, or even gave some away; but the method of preparation remained a closely guarded secret. On one occasion he disclosed his secret to a Dr. J. D. Krafft of Dresden for 200 thalers, on condition that it go no farther. But Dr. Krafft did carry it farther. He even went to England and showed the glowing substance to King Charles II and his court for a consideration. During this visit, and in return for some secret data about "uncommon mercuries", Krafft hinted to Robert Boyle that phosphorus was prepared from "somewhat that belonged to the body of a man."

From that moment the days of the secret were numbered, and soon after phosphorus became a commercial product on a small scale. The great Dr. Boyle, a real scientist, and considered by some historians to be the Father of Chemistry, was well acquainted with the importance of urine to alchemical theory and practice; it was probably one of the



Molten elemental phosphorus being loaded into a tank car for shipment. Protective clothing guards worker from dangerous splashes and spray

first things he tried as a result of the hint. Knowing what to look for and where, it was only a question of time before such a shrewd and experienced operator heated the residue from evaporated urine high enough to reduce the sodium ammonium phosphate with carbon already present or with added sand, and distilled over the free phosphorus into water. As with atomic fission in our time, the real secret was out as soon as the phenomenon was described. There remained only an engineering problem that yielded to developmental research. Robert Boyle was successful on September 30, 1680, though his method was not published until some time after his death.

"ENGLAND HAVE MY BONES" — About a century after the first discovery of phosphorus, it was discovered to be an important constituent of bones. In 1771 Karl Wilhelm Scheele announced that bones heated with sand yielded phosphorus; and a few years later he learned that it could be obtained more easily and in larger amounts by treating the bones with nitric acid. Its great value as an agricultural fertilizer was soon recognized and the phosphate industry took root in England. Bones treated with acid continued to be one of the main sources of phosphorus and applied directly to the soil as bone ash. But in Apparently the bones were at first simply ground up and applied directly to the soil as bone ash. But in 1840 the famous German agricultural chemist, Justus von Liebig, pointed out that if the bones were first treated with sulfuric acid the phosphate in them would be more soluble and therefore more readily absorbed by the crops. Two years later a certain John B. Lawes took out the first British patent for the treatment of bone ash with sulfuric acid, and the superphosphate industry was soon on its way. It developed with astonishing rapidity in England. No one asked too closely just where the bones came from. It is recorded that the numerous battlefields of the Continent were combed for the bones of old soldiers to be shipped to England for a final tour of duty in the phosphate acid vats.

Bones of all sorts make very good phosphate (there are about three pounds of it in the average adult skeleton), but bones were always in definitely limited supply. In those days some of the lower classes of Europe were beginning to rebel against the starvation which was normal then and is still normal in parts of the world. They insisted on staying alive and even on keeping their children alive. More intensive agriculture was indicated. Liebig accord-

ingly turned his attention to mineral sources of fertilizer. In 1857 he suggested that phosphate-bearing rocks could be ground up and treated with sulfuric acid just as readily as bones, and the results would be better for agricultural as well as sentimental reasons. This suggestion was well received as it fitted in well with industrial progress. The trick is to make a phosphate product soluble enough for the plants, but not soluble enough to be washed out by the first rain. Development was again rapid, and only five years later (in 1862) the production of superphosphates in England by this new method had reached the relatively enormous total of 200,000 tons per annum. It may relieve the minds of our more squeamish readers to learn that even our baking powders are no longer derived from bones, as they once were, and not so long ago either. Presumably these were the bones of animals, obtained from non-military abbatoirs.

One of the factors that helped the South recover from the economic disaster of the Civil War was the development of the phosphate rock industry in South Carolina in 1867 Almost at once the United States became the foremost phosphate-producing nation in the world. This position has been maintained ever since. There are very large deposits of the highly insoluble minerals *phosphorite,* $Ca_3(PO_4)_2$, and *apatite,* $CaF_2 3Ca_3(PO_4)_2$, in Georgia, Florida, the Carolinas, Tennessee, Montana and in some other states.

These two minerals are the source of all the phosphorus and phosphorus compounds of commerce today. They constitute one of our greatest natural endowments, simply because nothing will grow in soil that has no phosphorus in it. Cheap phosphorus means more food and therefore the element is responsible to a considerable degree for the great increase in the world's population during the last century. If all these additional hungry mouths are to be filled, artificial phosphate fertilizers in suitable form must be added to the soil.

BRANDT'S METHOD — Stripped of the extraneous alchemical verbiage found in the old accounts, Brandt apparently discovered phosphorus by evaporating large volumes of urine gently until the water and the more volatile chlorides were gone, adding sand to the solid residue and finally distilling the mixture in a retort at white heat Sooner or later the necessity of catching the distillate in water, not an unusual step in those times, was also discovered. The early directions for this preparation contained a wealth of

Night view of the elementary phosphorus plant of the Monsanto Chemical Company at Monsanto, Tennessee

abracadabra, and called for days of waiting for favorable developments and signs. These generally unpleasant details may be passed over quickly, but the remarkable fact remains that the underlying reactions described by Brandt, in so far as their basic chemistry goes, are the same as the reactions applied today in the most modern phosphate plants. This is true whether one is thinking of the blast furnace method, or the oil-fired furnace, or even the electric furnace which is most commonly employed in the United States today. It should be mentioned that the electrical methods applied in the plants of the Tennessee Valley Authority and Monsanto Chemical Company, for instance, are not electrolysis procedures, as in caustic production. The current is used solely as a source of heat.

We know now that Brandt must have reached a temperature in the neighborhood of 1450 degrees, C. to bring about the reactions and the distillation. Assuming that after ignition the very small proportion of phosphate in the residue was present in combination with lime, the first reaction was:

$$Ca_3(PO_4)_2 + 3SiO_2 \rightarrow 3CaSiO_3 + P_2O_5$$

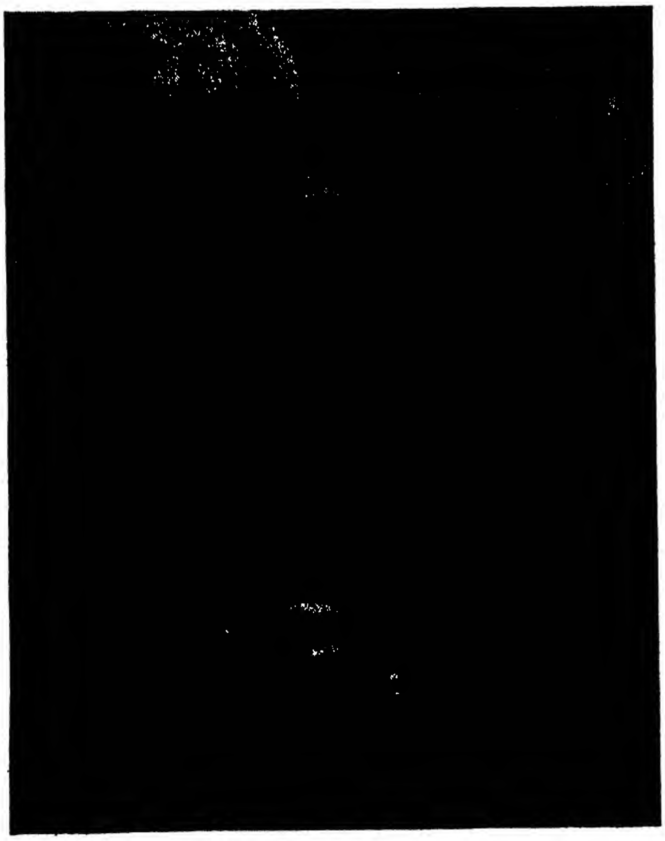
Remembering that carbon was also present from organic wastes such as urea, we have:

$$P_2O_5 + 5C \rightarrow 5CO\uparrow + 2P\uparrow$$

The final products are both gases at elevated temperature, and would readily pass into a distillate. As we have said, these are the basic reactions by means of which phosphorus is prepared today in the most modern chemical engineering equipment, with the help of enormous installations and with all sorts of electronic controls. After issuing from the furnace the phosphorus vapor is passed through a condenser and liquefied under water. It solidifies at 44.1 degrees, C. and is then stored and shipped out of contact with air.

The carbon monoxide gas that comes with it from the furnace is not wasted, but is led off to be used as fuel for the process. The calcium silicate slag which is formed in the first reaction drops to the bottom of the furnace and from here it is drawn off.

Piles of crushed phosphorus-bearing rock awaiting processing. Such rock is by far the most plentiful source of phosphorus



WHITE, RED AND BLACK — It is important to remember that the product so obtained, that is, by condensing phosphorus vapor, is always the extremely poisonous white phosphorus, sometimes called "yellow" because of a superficial layer it acquires on exposure to light. But white or yellow, phosphorus will "dissociate" one from wordly affairs quickly and efficiently. Phosphorus shines in the dark and in the cold. It was this astonishing phenomenon of "cold light" that intrigued the early workers. Some of them used to spend their days evaporating huge amounts of urine in a vain effort to increase the yield and to obtain enough phosphorus to light up a room. The illustrious philosopher, Gottfried Leibniz, was much interested in illuminating a room for his patron, Duke Johann Frederich of Hanover, with the material.

The light from phosphorus is not due to internal changes, as in the case of radium, which also glows in the dark. It is due to slow oxidation. But if heated in air up to 30 degrees, C.—cooler than the temperature of the human body—the oxidation is so accelerated that white phosphorus bursts into flame. Since it burns at such a low temperature, the element must be protected from oxygen by covering it with a layer of water.

When white phosphorus is enclosed in a vessel protected from air and heated to about 250 degrees, C. a remarkable transformation takes place. The white solid turns to a red powder consisting of minute monoclinic crystals, and a good deal of heat is liberated at the same time. This substance is the famous safe red phosphorus. It is safe for a number of reasons. It is no longer a particularly toxic substance. It is now insoluble in all known solvents, a fact that probably accounts for its much decreased toxicity. It does not have to be kept under water any more to avoid spontaneous combustion. It does not catch fire now below 330 degrees, C. In addition, its melting point has jumped from 44.1 to 590 degrees, C. and this only when squeezed with a pressure of 43 atmospheres. In other words, it never would melt under ordinary conditions. If heated sufficiently, it would go directly from a solid into a gaseous state, i.e., it would sublime.

There is one more kind of phosphorus that comparatively few people have seen, namely, black phosphorus. This does not refer to the discolored product contaminated with dark impurities that is sometimes observed. It is an artificial allotrope formed by Professor Percy Bridgman, the famous Harvard authority on high pressure methods, by heating white phosphorus at 210 degrees, C. under a pressure of 15,000 atmospheres. It turns out to be a heavy material that looks like graphite. Unlike other forms of phosphorus, it is able to conduct an electric current to some extent.

MICROWAVES IN COMMUNICATION

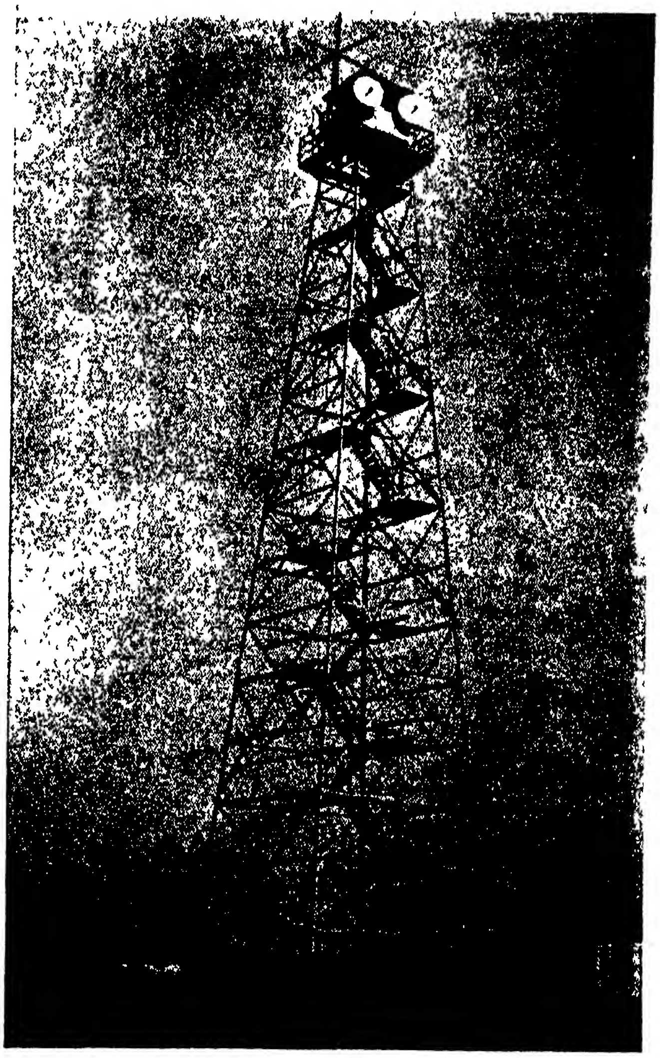
Highest Frequencies of the Radio Spectrum, Applied in Radar, May Ease the Congestion of U. S. Telephone and Telegraph Lines. An Account of How Microwaves Are Already in Use for Relay Transmission Between Cities

By Deane H. Uptegrove, Jr.

EVER since Samuel Morse sent his first message over a telegraph wire, the demand for telephone, telegraph and other wire-using services has been increasing steadily through good times and bad. If each communications circuit in use today required an individual pair of wires, the number of pairs needed to meet the demand between any two major cities in the United States would be staggering. This condition is relieved by standard circuits which make it possible for three telephone conversations and several telegraph signals to be carried simultaneously over only two pairs of wires. On branch routes this is usually sufficient. Economical operation over main arteries, however, requires far more drastic measures. The use of modulated carrier currents has improved the situation by making it possible to send hundreds of telephone conversations or telegrams over the same pair of wires at the same time. Still greater efficiency has been obtained by the use of coaxial cable. But even coaxial cable is limited in the number of communications circuits that it is able to carry.

Another growing demand for communications facilities is made by the television industry. The recent strides that have been made toward bringing television into the home of the average American have focused attention on the fact that television broadcasters badly need a network system to transmit programs over the entire United States. Because of the wide range of frequencies involved, ordinary wire and cable facilities are not suitable for television transmission except over very short distances. Coaxial cable is used regularly for television, but is not completely satisfactory because it can transmit frequencies only up to three megacycles. A minimum of four megacycles would more nearly meet television requirements.

The shortage of communications circuits has been accentuated by the shortage of copper which began with the war. And to all of these difficulties must be added those which are accepted as routine in the operation of cable and wire systems: ice, high winds, falling branches and trees, poles broken by wandering automobiles. Even when cables are carefully pro-



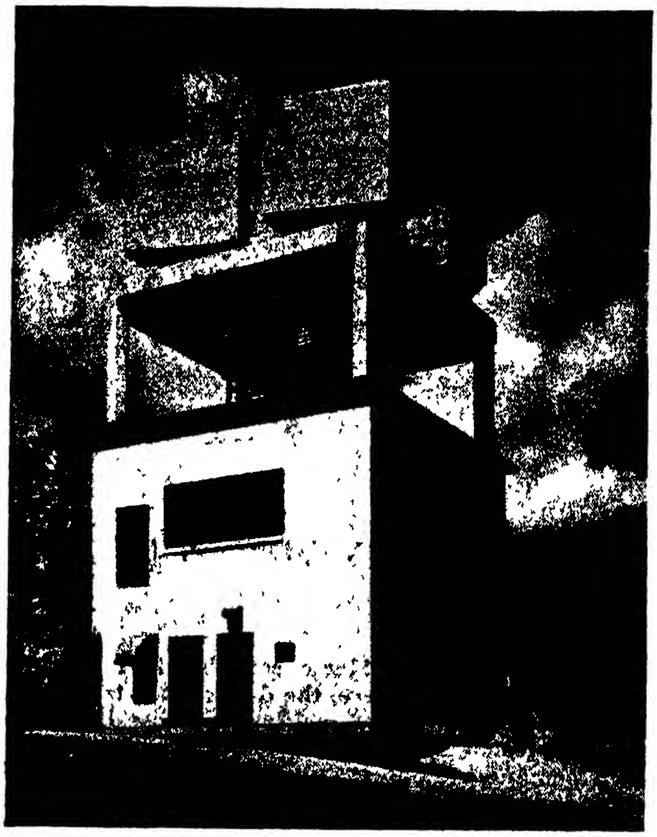
A relay tower in Western Union's microwave system. The system can handle over 2,000 messages simultaneously

tected in underground conduit, accidents can happen.

POINT-TO-POINT RADIO — All this led engineers long ago to consider radio for point-to-point communication between land stations. There has already been considerable use of radio in overseas telephone service, ship-to-shore telephone, and more recently the mobile telephone service for automobiles and trucks. The use of radio as a substitute for wires and cables, however, has not been practical because the useful radio frequency spectrum of earlier days simply was not big enough to satisfy the demand. The Federal Communications Commission, in cooperation with other countries, had to dole out the available frequency assignments with the greatest care, permitting the use of long distance frequencies only for those purposes where there was no alternative to radio. Television or multi-channel communications service were out of the question because they would use such wide chunks of spectrum space that there would be no room for anyone else at all.

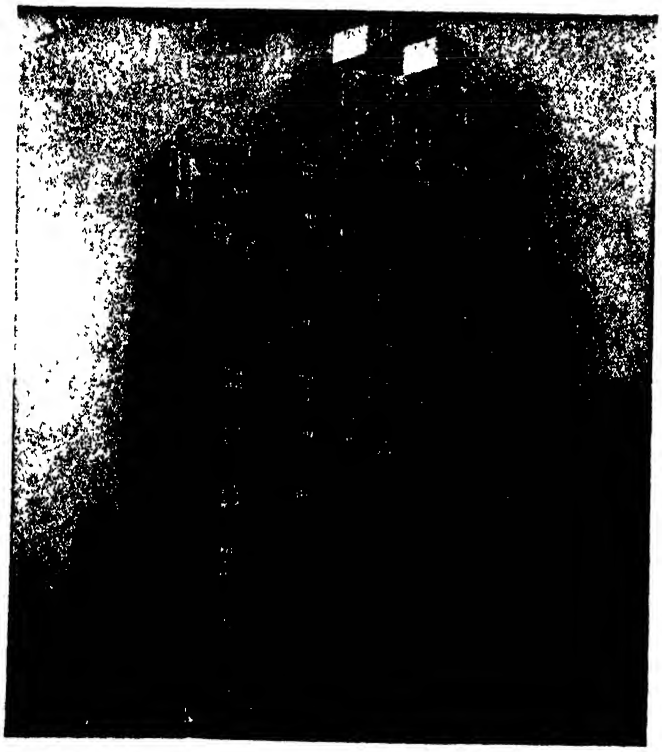
Next to the atomic bomb, probably the greatest development that came out of the war was radar and the exploration of the vast regions of the electromagnetic spectrum above 3,000 megacycles. This made room for all kinds of new uses for radio. Some day even the microwaves will probably be as crowded as the longer waves are today (frequencies as high as the Television and Frequency Modulation Broadcasting frequencies have already been the scene of many battles). For the present, however, there is room for nearly anyone who wants to get into the microwave region.

These super-high frequencies are the answer to the problem of new channels for point-to-point communication. Even the broad bands of modulation frequencies required for high quality television transmission are a small percentage of the usual carrier frequency. The highest frequencies are not seriously troubled by rain, snow, or fog. Unlike the lower frequencies, they are not affected by static and most kinds of man-made interference. Another advantage is that they can be transmitted by highly directional antennas of conveniently small dimensions. The horn used in the Bell System antenna described below, for example is about ten feet wide. If a similar horn could be built to work on four megacycles it would have to be almost two miles wide!

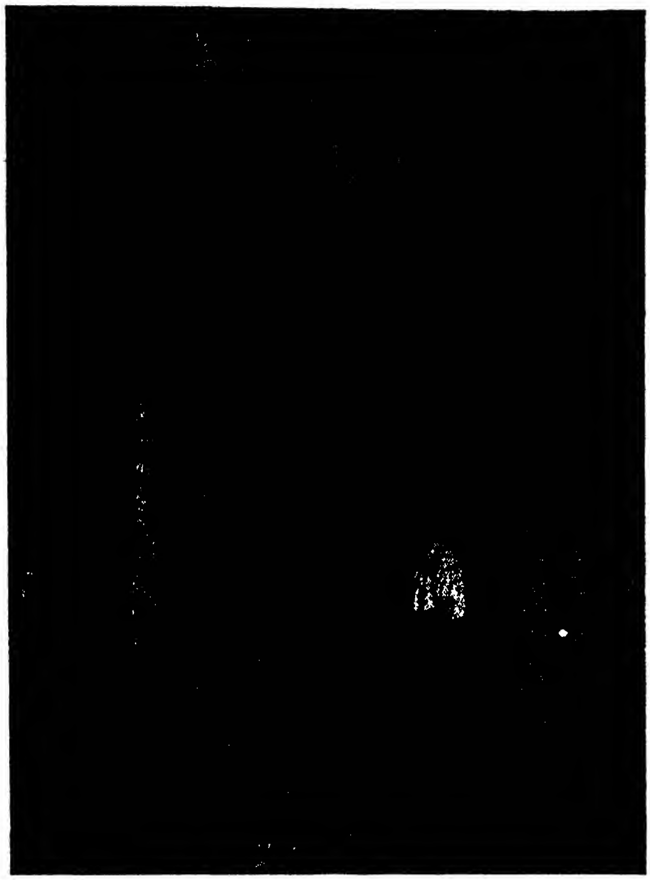


One of the stations in the microwave relay links between New York and Boston. Directional antennas are mounted on roof

The Bowdoin Square Building, which is the Boston terminal of the Bell System's New York to Boston microwave relay route. The antennas can be seen at the top of the building



LINE-OF-SIGHT PATH — The greatest disadvantage in using microwaves for long distance communication is that these waves follow a "line of sight" path and ordinarily do not follow the curvature of the earth beyond the horizon. This means that it is necessary to have repeater stations located at intervals along the route, generally situated on the highest available hill in order to have the longest reach to the next horizon. However, the advances in microwave technique in the last few years have made the design of circuits, waveguides, antennas, vacuum tubes and other microwave equipment a much less formidable problem. Already some engineers contend that frequent microwave repeaters are more economical to maintain than a cable system. It is easy to see why the domestic wire and cable companies, notably the Western Union Telegraph Company and the American Telephone and Telegraph



Rear view of the relay bays in a station of the Bell relay link. Note the wave guides leading up to ceiling

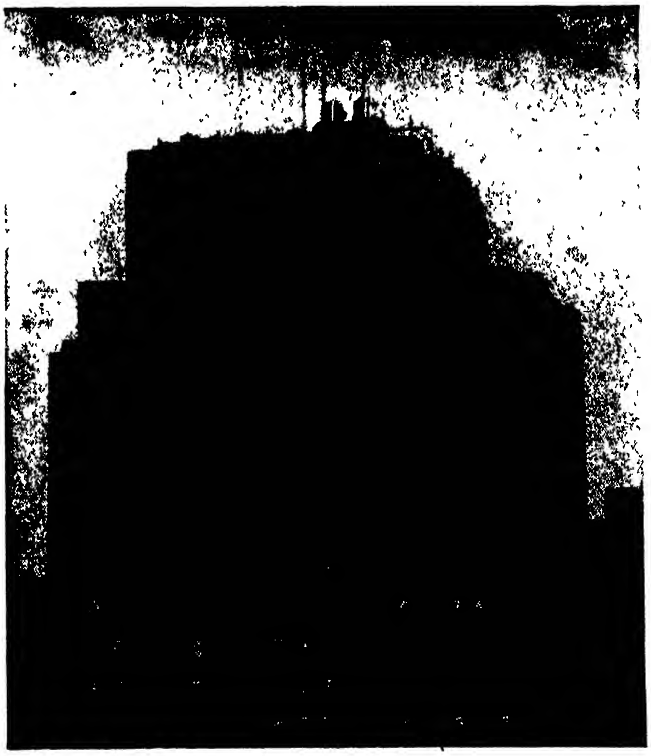
The multiplexing system used in microwave transmission divides the 30 to 150,000 cycle band into 32 voice-frequency channels, each about 3,000 cycles wide. Each voice frequency channel can be divided into eight multiplex telegraph channels and by means of a time-division system, each multiplex telegraph channel can be used for four teleprinters. All this adds up to making possible the transmission of *Over 2,000 Messages at the Same Time,* half in one direction and half in the other.

NEW YORK TO BOSTON — American Telephone and Telegraph (the Bell System) has recently put into operation a microwave system between New York and Boston. This is also being extended from New York to Chicago. Between Boston and New York the microwave beam makes eight jumps over seven intermediate radio relay stations spaced about thirty miles apart. On the roof of each radio relay station are four antennas, two facing along the route toward New York and two facing along the route toward Boston. This allows for two-way operation with one antenna of each pair for transmitting, the other for receiving. The antennas are horns with metal lenses in their ten-foot-square openings. These metal lenses consist of a series of metal vanes arranged in such a way that they produce the same effect on radio waves as a glass lens produces on light waves. They are covered with a sheet of plastic across the openings to keep out birds and ice. The beam from this type of antenna is less than two degrees wide—so concentrated that practically no power can escape from one antenna into any other than that for which it is intended. It is therefore possible to design the intermediate repeaters simply

Company, are seriously interested in microwave radio.

Western Union has been operating an experimental microwave system between New York and Philadelphia since 1945, and has plans for extending it to cover nearly all parts of the country. The Western Union system operates in the neighborhood of 4,000 megacycles (7½ centimeters) with relay points at an average of every 25 to 60 miles. Antennas with parabolic reflectors are used, located on towers from 60 to 120 feet in height. On sections longer than about 15 miles, fading due to reception over multiple paths is conquered by diversity reception making use of two receivers whose antennas are separated vertically by about 25 feet. The 4,000 megacycle carrier frequency is modulated by a one megacycle subcarrier, and this in turn is frequency modulated by multiplexed telegraph signals in the band of 30 to 150,000 cycles. At the intermediate relay stations the received signal is demodulated back to one megacycle, and this one megacycle sub-carrier is used to modulate the outgoing signal. The sub-carrier is not demodulated except at the ends of the line. This makes possible considerable simplification of the equipment at these intermediate points. In fact, modulators and demodulators do not have to be too accurately in line because both the carrier and subcarrier are frequency modulated. This method of transmission makes possible some distortion of wave form without affecting the multiplexed telegraph signals it carries.

The New York terminal of the Bell System's New York to Boston microwave chain at 32 Avenue of the Americas



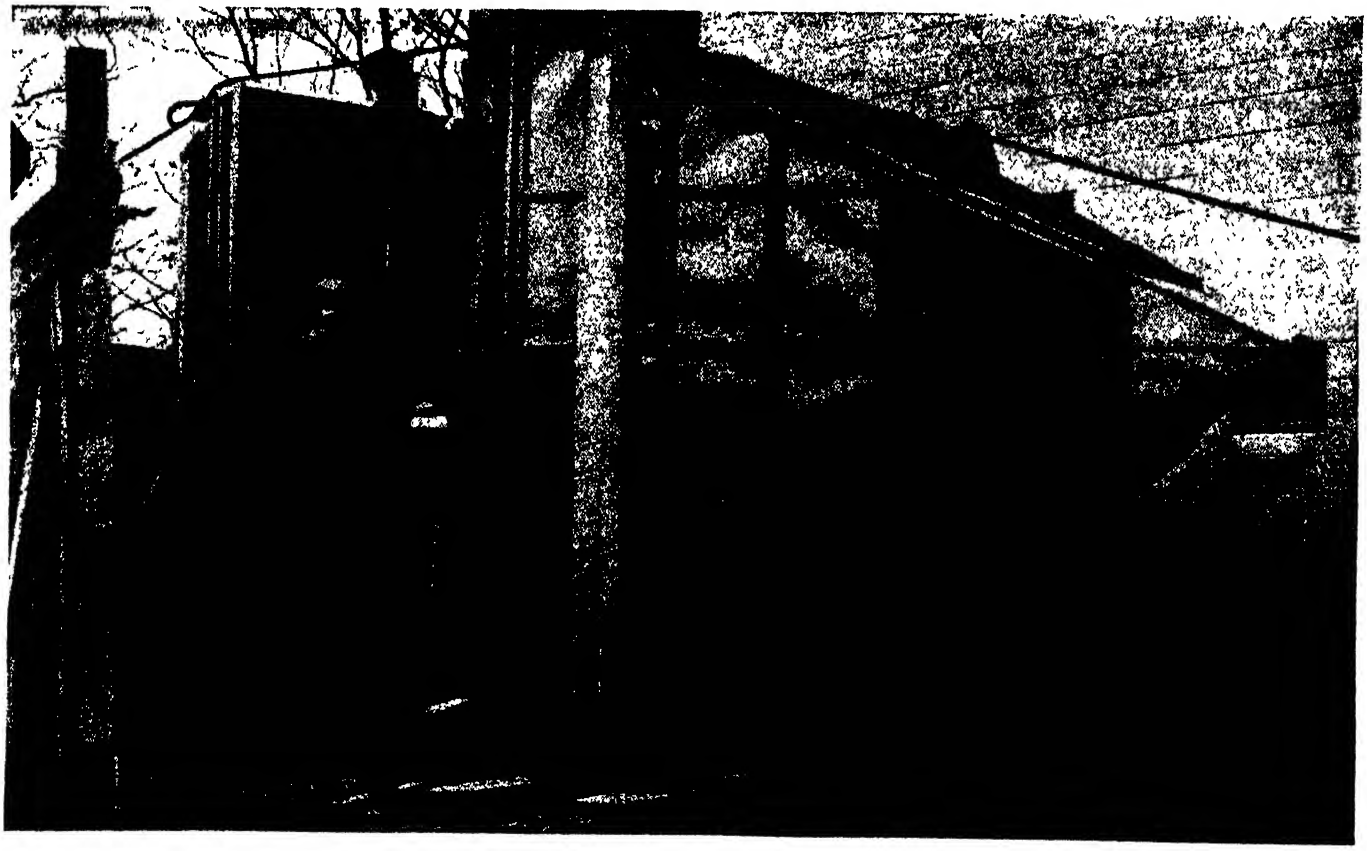
as broad band amplifiers, able to handle substantially any type of signal using any kind of modulation. At present this system is set up to use frequency modulation, but amplitude and pulse modulation are being tested as well. For operation of these circuits, frequencies in the range 3700 to 4200 megacycles have been assigned by the F. C. C. This should give room enough for at least six two-way broad band channels on a route. Each of these can be made wide enough for color television if required.

In addition to the accomplishments of these two organizations, several television broadcasters have set up microwave radio circuits and several more are at the discussion stage. The Philco Radio and Television Corporation has a system now working between New York, Philadelphia and Washington to interchange programs between WNBT in New York, WPTZ in Philadelphia and WNBW in Washington. The General Electric Company has a microwave link to connect WRGB in Schenectady with New York City. The Raytheon Manufacturing Corporation has plans for microwave radio links between San Francisco and Los Angeles and between New York and Boston, but does not have any on the air at the present time. Various plans have also been suggested for coöperative arrangements for television networks between groups of broadcasters.

TELEVISION PICK-UPS — Microwaves are also often used in television broadcasting for local pick-ups from sports events, news incidents and other points of interest remote from the studio but within the "line-of-sight" range. Wire facilities are also used for this purpose, but this use is generally limited to short distances and often involves extensive rearrangements of existing cables. The Bell System has microwave radio equipment suitable for television pick-ups, and most of the broadcasters have specially equipped trucks and portable transmitters which can be quickly set up almost anywhere. For example, when President Truman was given an honorary degree at Princeton last spring, the ceremony was televised and sent by microwave from one of the taller Princeton buildings to Mount Rose, New Jersey, which is a relay point in Philco's New York-Philadelphia system. The Philco system carried the program to television station WNBT in New York and from there it was sent back over the American Telephone and Telegraph Company's coaxial cable to Washington.

Microwaves as a means of point-to-point communication have a long and hilly road ahead. There are technical differences of opinion and there are those who say that it is too expensive. The need for this type of facility, however, is urgent and the highest hills have already been passed. Engineers are becoming more and more familiar with how to handle this great new region of the radio spectrum. In the years ahead we can expect to see the United States covered with a series of microwave networks connecting every major city, bringing television programs from every part of the country to every other part of the country and carrying thousands of telegrams and telephone conversations without cables or wires.

A metal lens assembly being inspected and cleaned before being hoisted into position on the relay station's roof. The metal lens focuses the microwaves much the same as a glass lens focuses light, and it permits the use of far less transmitting power than would otherwise be possible



PHOTOCHEMISTRY IN INDUSTRY

Electromagnetic Radiation, Engineering Chemical Reactions Through the Use of Specially Designed Lamps, Is a Powerful Tool in Many Modern Processes

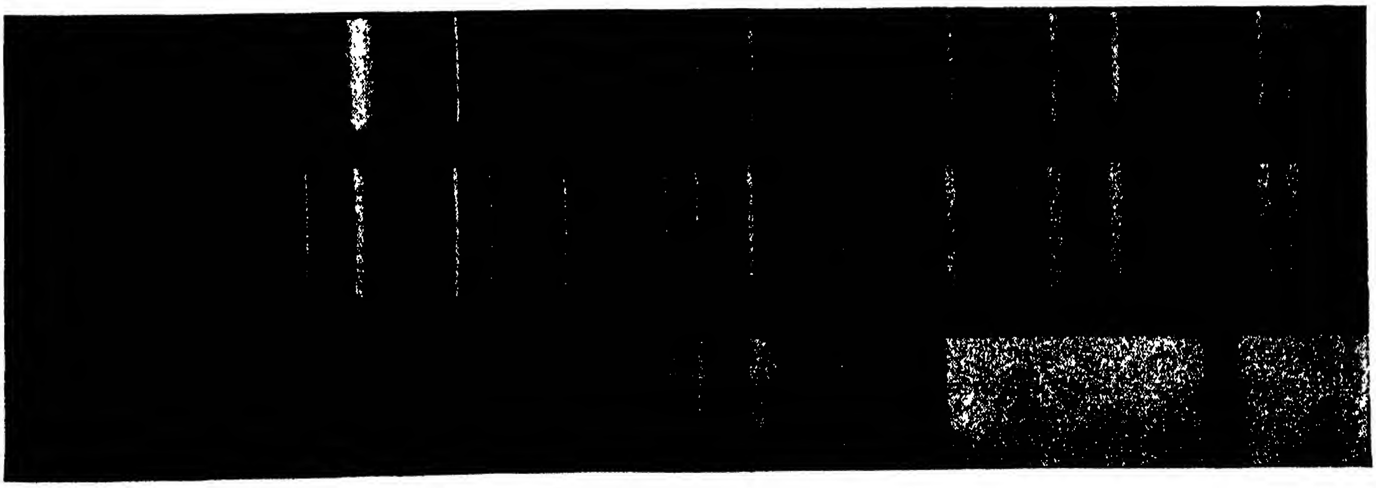
By E. W. Beggs
Westinghouse Lamp Division

DURING the next five years, only a day in scientific history, we will see more new uses made of the chemical effect of light and ultra-violet rays than in all the history of the chemical sciences. People absorb ultra-violet through their skin and the magic of photochemistry creates Vitamin D for bodily health. The photographic arts, first widespread field of use for the chemical effects of light, enrich our lives with pictures. Blueprint and photocopy machines gradually supplant the mimeograph and even the typewriter. Bleaching is done indoors under batteries of ultra-violet lights. Now new chemicals and improved chemical processes are created through intelligent application of radiation to solutions, gases, films and mixtures as they pass through chemical reaction chambers.

Photochemical action results when electromagnetic waves such as light and ultra-violet cause a chemical change. In photography, the light rays change the silver salts on which they fall so that black silver metal is left after the film is developed. In growing plants, chlorophyll reduces carbon dioxide and forms carbohydrates through the aid of radiant energy from the sun. A mixture of hydrogen and chlorine is relatively inactive in the dark but these gases combine with explosive violence if light rays fall upon them. Photochemistry deals, therefore, with a wide range of reactions. In some the radiations are merely a "trigger" or catalyst. In others, the radiant energy is absorbed and becomes a part of the potential energy stored in the products of the reaction. Photochemical reactions vary widely in mechanism as well as in the character of their products. Nonetheless all reactions which take place primarily because of radiation are called photochemical.

The history of photochemistry is long and full. The knowledge of Photosynthesis in plant growth and the bleaching properties of light are as old as the science of chemistry. The drying and hardening of paints, the making of patent leather and the rela-

Photospectrographs of low, medium and high pressure mercury discharges in quartz (top band, 10 microns; center band, 35 centimeters; bottom band, 100 atmospheres). Increasing pressure causes shift toward longer wave lengths



tionship of sunlight to human health came long before photography and today's budding market for radiations which promises to create new, cheaper and better products of many sorts.

The action involved in photochemistry is generally the same in all its applications. First, of course, the radiations must be absorbed by the chemicals involved. Without absorption, there is no reaction. Second, the absorbed rays must work a change in the reagents. Generally this consists of a displacement of an electron in an atom or molecule, resulting in increased chemical activity in one or more of the reagents. If this promotes a reaction that would not occur in the dark, the action is photochemical. Such reactions, of course, take many forms. Some of the most common are exothermic, others are endothermic. In the former, where heat is given off, the reaction takes place slowly without light. Here the radiations can perform the function of a catalyst. In the endothermic, as in plant growth, radiant energy becomes an essential part of the reaction. The energy of radiation is ultimately given up and appears as increased potential energy in the end products. This is generally the result of a reduction process.

Photosynthesis in plants involves the absorption of infra-red radiation, visible light and a small amount of near ultra-violet rays. Photographic processes generally utilize visible light, although some limited applications depend on ultra-violet or infra-red energy.

The absorption of near ultra-violet, at a wave length of about 3,650 Angstroms, causes a marked increase in the chemical activity of chlorine. Under the influence of ultra-violet, chlorine combines readily with benzene, toluene and similar compounds to create insecticides and other valuable end products. The radiations at about 2,967 Angstroms in the ultra-violet region manufacture Vitamin D in the human skin.

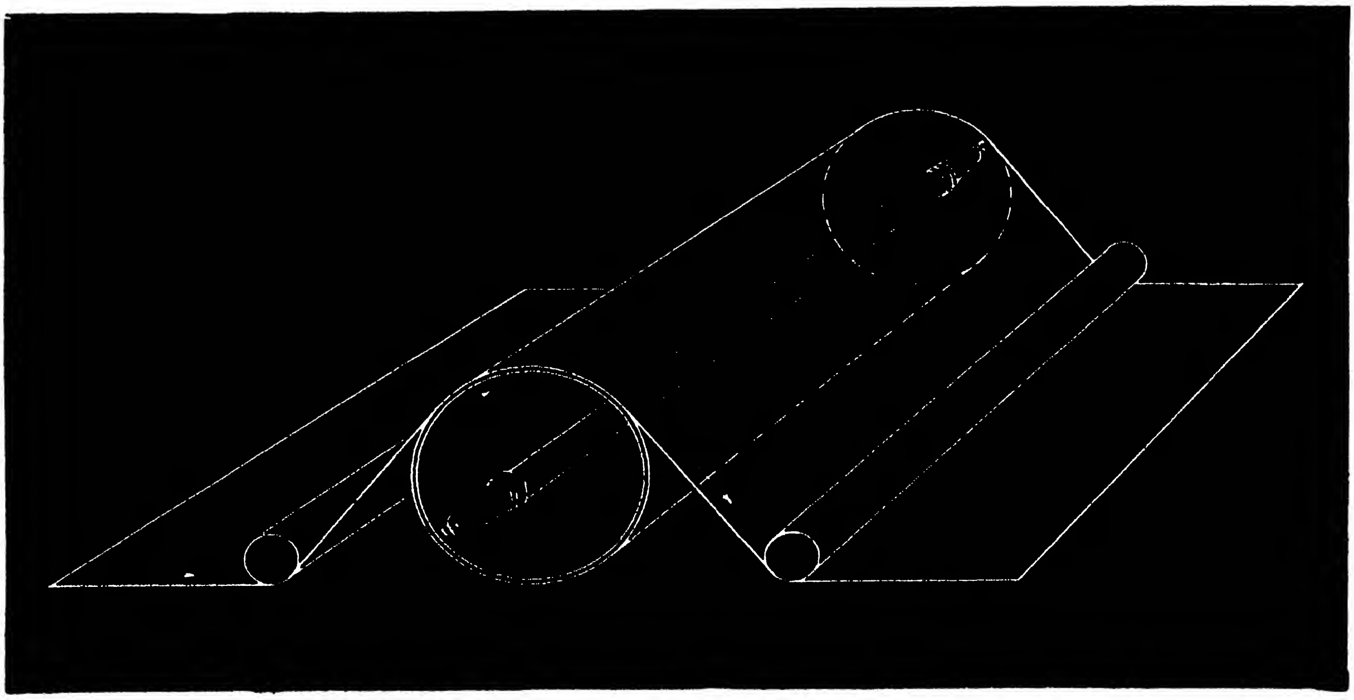
Rays shorter than these are useful in stimulating the chemical action of oxygen, hydrogen and other elements.

FROM INFRA-RED TO X-RAYS — So the entire range of the electromagnetic spectrum, from the infra-red down to just short of X-rays, is applied in photochemistry. Today, however, the greatest activity is in the application of those radiations which induce chlorine to combine with hydrocarbons. This is largely because the radiations required for this may be readily generated and controlled. Mercury vapor discharge lamps of suitable design generate the rays efficiently and in large amounts. Aluminum reflectors direct the rays and special glass plates and tubes transmit them with relatively little loss.

The spectrum of mercury consists of spectral lines ranging principally from 1,850 to 10,000 Angstroms. At low pressures, the most powerful radiation is in the line at 2,537 Angstroms. As the pressure rises, due to heavier loading of the discharge tube, the power in the longer wave length lines increases Finally, at extremely high pressures such as 100 atmospheres per square inch, where heavy walled quartz discharge tubes are required, the long ray lines are stronger and wider and an important background band of energy appears. Thus the type of radiations obtained from mercury vapor lamps can be controlled somewhat by varying the loading of the discharge.

Each photochemical reaction has its own special requirements but all need the proper source of energy. This naturally involves the lamps and equipment used to reflect and transmit the necessary radiant energy. First, of course, the chemist must know what spectral lines or bands are needed. Second, he must know what intensity of radiation is required. Third, he must consider the familiar

A simplified sketch of a continuous blueprint machine. The long tubular light source at the center of the rotating drum assures even exposure



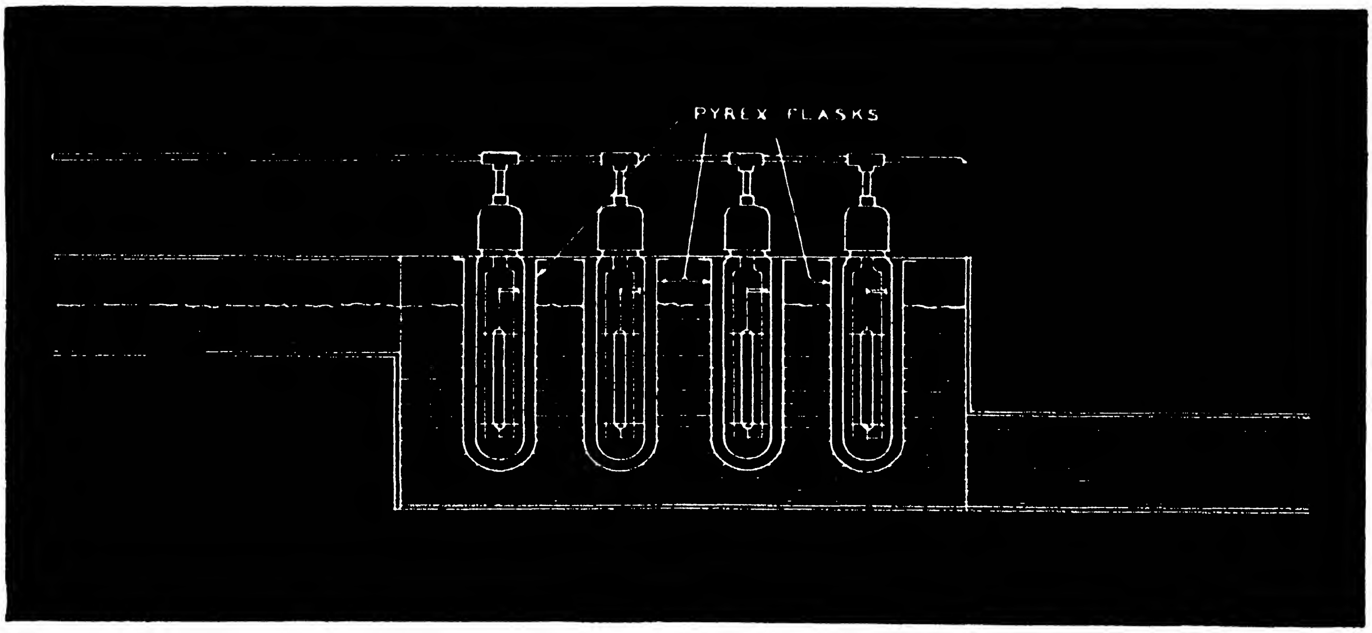


Diagram of a battery of lamps enclosed in pyrex flasks, arranged for a continuous flow operation

physical-chemical factors of pressure, temperature and concentration. Last, he must calculate capacity and speed which determine the scale of a particular photochemical process and which in the end set the wattages of the lamps and dimensions of the equipment.

CHLORINE AND BENZENE — A laboratory experiment in which chlorine and benzene are irradiated with ultra-violet, causing them to combine and form one or more of the chlorobenzenes, is photochemistry reduced to its simplest terms. Chlorine gas is dissolved in benzene until the solution turns to a strong yellow color. When a photochemical lamp is placed over the beaker containing the solution, the rays activate the chlorine so that the solution becomes colorless. The top layer clears first. Then the colorless layer becomes thicker or deeper. In a few minutes the entire solution is clear as water, all the available chlorine having combined with the benzene.

This reaction may be carried out in the open air at room temperature under a chemical hood with the simple equipment described. More elaborate operations require enclosures for the lamps, reflectors to redirect the rays most efficiently to the reagent, glass plates or piping to separate the lamps from the gases or solutions. To these details must be added facilities for control of temperature and pressure as well as for the proportions or concentrations of the reacting chemicals.

A study of some representative photochemical installations now in regular operation shows several basic arrangements of the lamps and auxiliary equipment. Most photochemical reactions can be conveniently carried out by one or another of the designs now used. Certain applications, of course, will be encountered which require new methods of applying the radiations.

The oldest and simplest photochemical installation is very much like the experiment described above, with the lamps suspended over the reaction vat. The reagents may be stationary or may flow past the irradiation area. This arrangement has been used experimentally for the precipitation of uranium salts. It can also be used for the chlorination of benzene or other similar reactions.

Another method of applying radiation in a photochemical process is to mount a single lamp in a glass tube that penetrates deep into a kettle of reacting solutions. This encloses the reagents and provides protection for the lamp and its wiring system. Where the reaction is to be of the continuous flow type, a similar system utilizing a succession of enclosed lamps suspended in the solution is often used. Where gases or fluids are to be carried through the irradiation area in transparent glass pipe, the flow may be arranged around the lamp. Here the lamp is provided with a continuous flow of clean cooling air and the electrical system is protected from fumes because the reagents are completely enclosed.

RAYS ARE REFLECTED — In all enclosed photochemical systems, especially where the reagents are contained within clear glass enclosures, the radiations which pass completely through the reaction area should be reflected back and conserved. Aluminum reflectors are generally recommended. If the reflector enclosure has appreciable width, it should be provided with a top and bottom reflecting surface. The single lamp with a surrounding reacting chamber is a very efficient arrangement because it utilizes the radiations directly with a minimum of loss in reflectors and glass. It can be provided with temperature control by water baths and, of course, an appreciable amount of pressure control is also practicable.

Water may be used effectively to surround the reaction tube because light and ultra-violet rays pass through water with little loss. A temperature controlling water bath of clean tap water transmits practically all radiations but the infra-red or heat rays. In fact, the losses of photochemical energy through

water layers up to several inches thick are far less than through ordinary glass pipe.

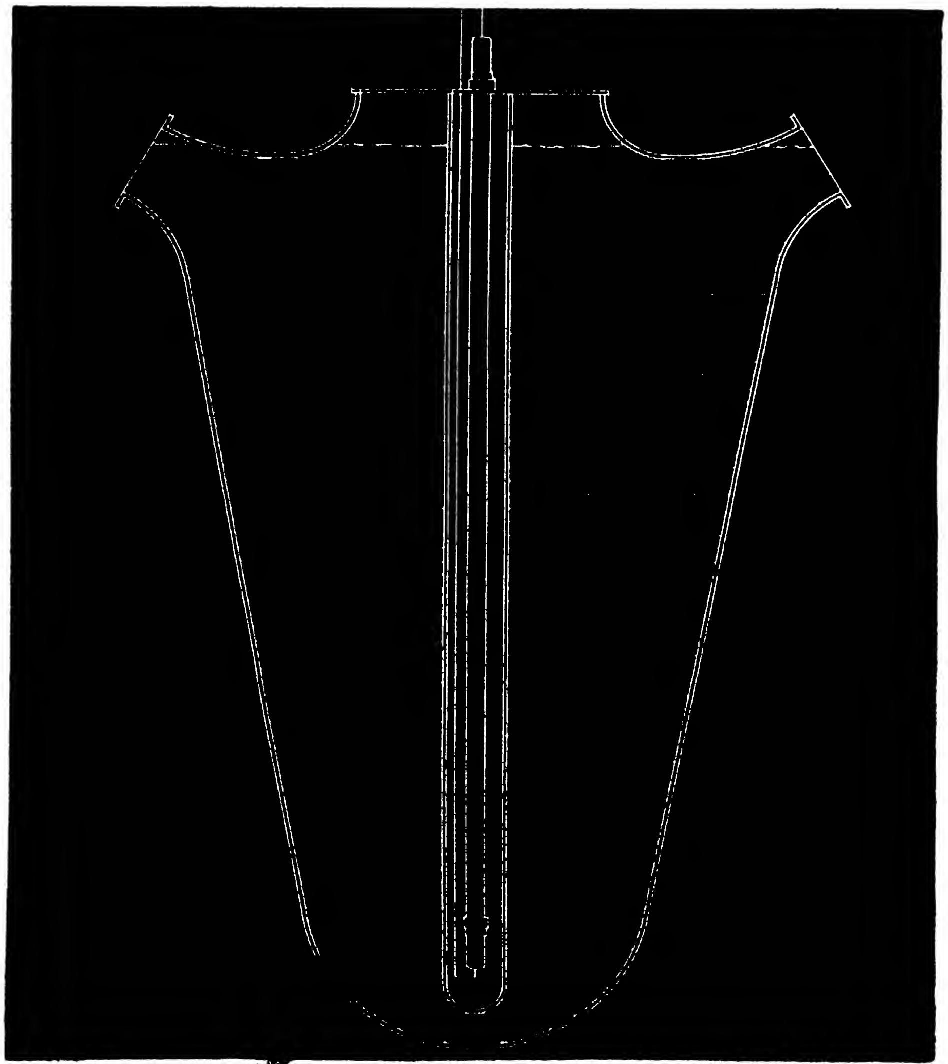
Most of the representative installations described above find their widest use in chlorination reactions. They are also suited to reactions involving other halogens and to reduction processes. For polymerizing reactions and the irradiation of films and coatings, a different treatment is required. Sometimes the film is treated alone and sometimes it is treated as a coating on paper or fabric or on many types of solid objects.

Photography and the photographic arts are all basically photochemical. In fact, except for photosynthesis in plants, photography is the most widespread and important photochemical process. Blueprinting, photolithography, photocopying and similar operations in this field require the same general equipment and technique as photography. Light and ultra-violet rays fall on coated paper or plates and cause the desired reaction—generally the recording of an image for reproduction in printing. If it is to be a blueprint—or the more popular "black print" or "brown print"— the original and the printing paper are pressed together and the radiations react on a special coating to develop a reproduction. This generally requires a long tubular source of light of a length appreciably greater than the print. The lamp is ordinarily mounted in the center of a rotating drum, which revolves at a steady rate to give the print a uniform exposure and thus even density.

Where a photoprint is to be used in photolithography, the picture is generally mounted on a frame and photographed. Here the intensity of radiation must be high and uniform. For such an operation, individual high-powered mercury vapor lamps may be mounted in portable units directing their light at the picture from both sides. A more convenient method is to mount two or four long tube lamps to frame the photograph with light. The lamps must be mounted so they are in front of the plane of the picture sufficiently to provide brilliant yet uniform illumination.

All of these considerations in photochemistry apply forces which are not completely familiar to the chemist. In conclusion, a brief discussion of the basic principles of using radiation and electricity in photochemistry may make the processes described previously even clearer.

RADIATION — Radiant energy involved in photochemistry ranges from about 10,000 to 1,000 Angstroms and includes visible light from about 4,000 to 7,000 Angstroms. All of these radiations are reflected, refracted, transmitted, diffused and absorbed



Sectional drawing of a single 3,000-watt lamp mounted in a glass tube and penetrating deep into the solution in the photochemical reacting kettle

like light. The rays travel in a straight path until they are redirected or absorbed. In an open space the intensity of the light or radiation decreases as the distance between the source and the surface irradiated is increased. With concentrated light sources the intensity reduces rapidly—that is, with the square of the distance. With elongated sources where the surface is quite close to the source, the intensity drops off about in direct proportion to the distance.

Almost complete absorption of all radiation takes place when the rays strike a rough, dark surface. Partial absorption takes place when the rays strike a colored object or pass through a colored solution. For example, red rays are absorbed by a blue paint or blue solution, and blue rays are absorbed by red paint or a red solution. Certain colorless materials absorb infra-red and/or ultra-violet. For example, window glass absorbs ultra-violet and clear water absorbs infra-red. A solution of chlorine in benzene absorbs practically all rays in the near ultra-violet —from just beyond the visible violet to about 3,000 Angstroms in the erythemal band of the spectrum. Quartz transmits almost all radiations from 1,850 to well beyond 10,000 Angstroms.

Reflectors are either polished (specular) or diffusing (matte) Rays that strike a polished reflector "bounce" off at a definite angle like a ball from the cushion of a billiard table. Rays that strike a diffusing reflector are reflected in many directions and diffused. Most reflector materials reflect all visible and infra-red wave lengths well but only a few also have a high reflectivity in the ultra-violet. Aluminum has an excellent reflecting power for all wave lengths, including ultra-violet down to 1,850 Angstroms. Alzak finished aluminum is the recommended type because this finish retains its high reflecting efficiency under adverse treatment.

Transmission and absorption are, of course, optical opposites. Distilled water and clear "tap" water transmit almost 100 per cent of the light and near ultra-violet rays if the water layer is only a few inches thick.

Refraction or bending of light rays as they pass through lenses or prisms is only occasionally involved in photochemistry. The laws of optics that apply to visible light also apply to photochemical radiations. The rays are bent as they pass through the prism or lens and thus can be concentrated or spread as needed. Generally photochemists need diffused and uniformly distributed energy. Therefore lenses are not often necessary. This is also true of specular reflectors, particularly if they are bent into parabolic or elliptical forms. These and lenses may develop local "hot spots" or high concentrations of

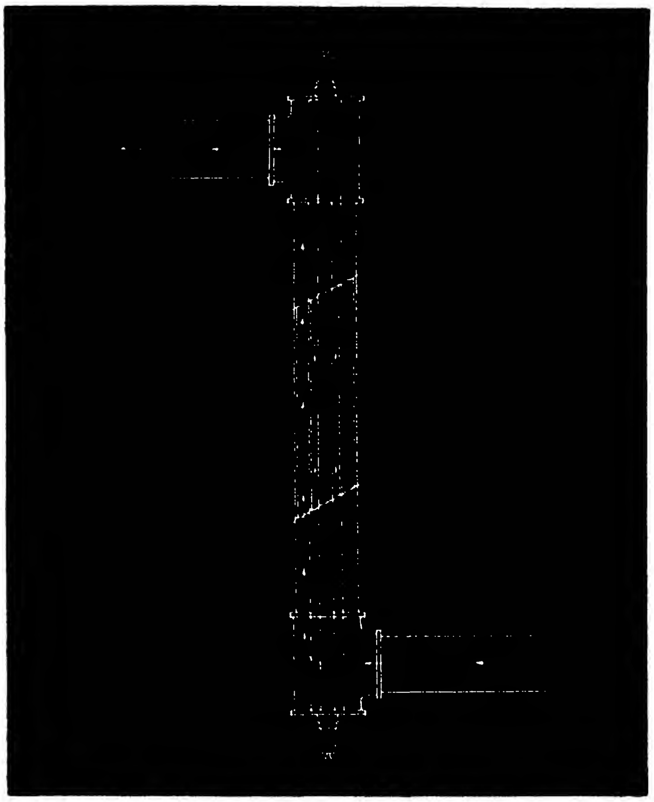
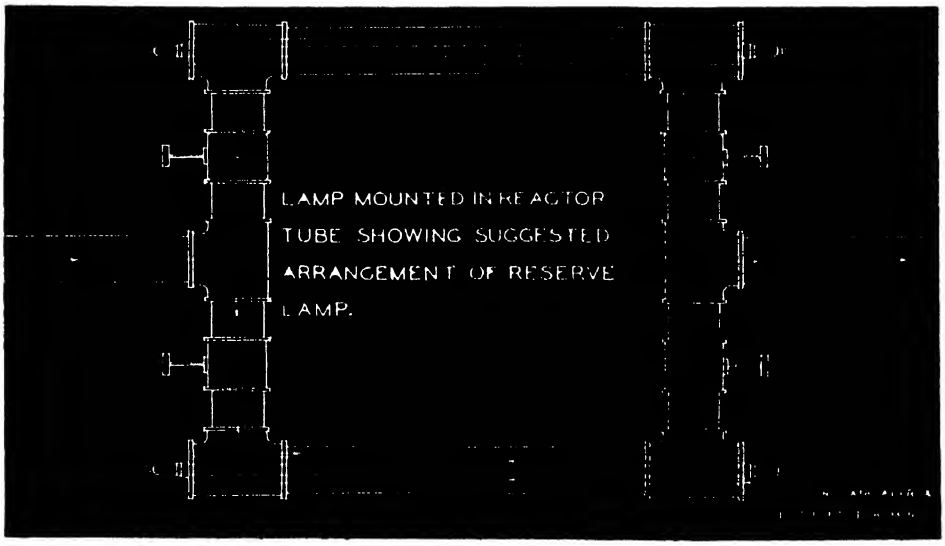


Diagram of a typical installation for the irradiation of a liquid or a gas. Tubular lamp is shown in dotted lines



By equipping the photochemical reactor tube with such a reserve lamp arrangement, the necessity of interrupting the process to replace a lamp is eliminated

energy which may have an undesirable effect on the chemical reaction.

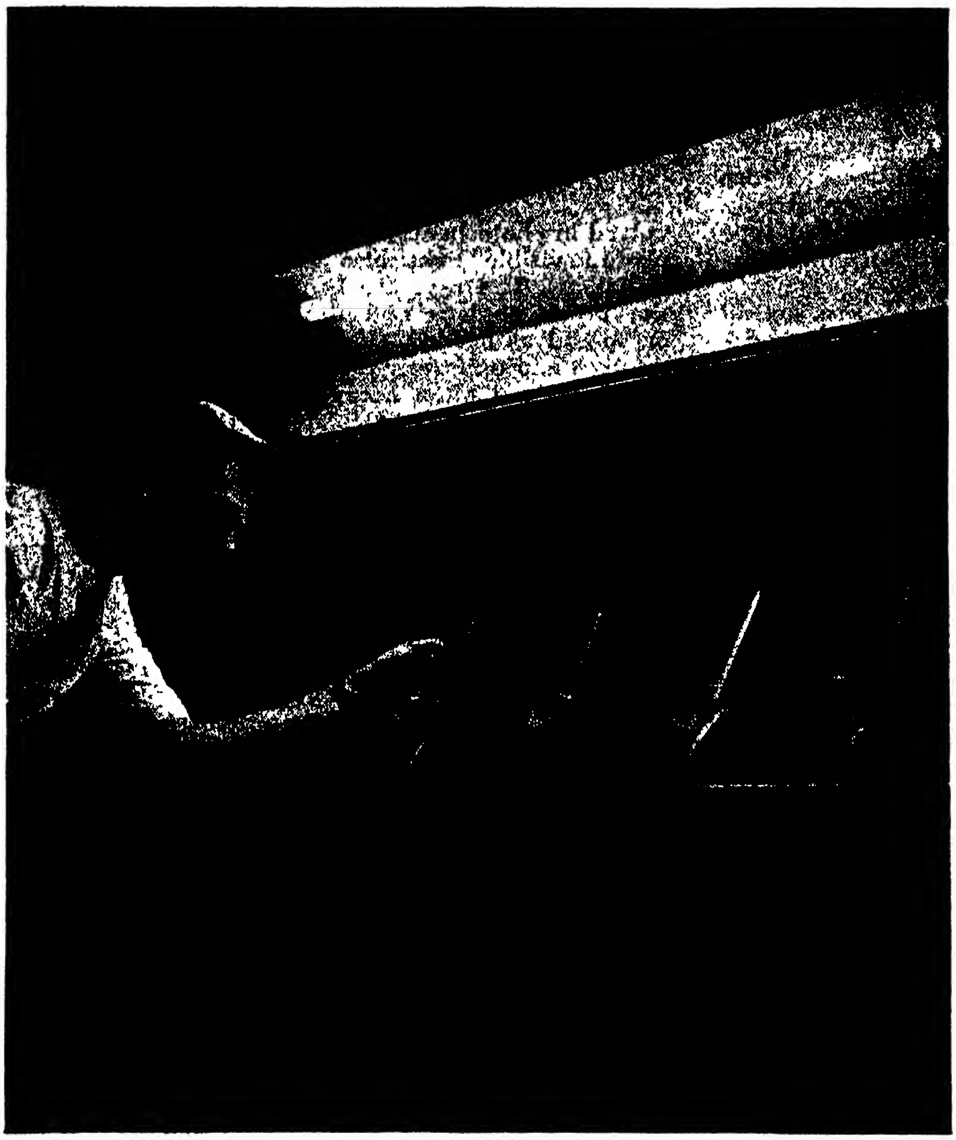
ELECTRICITY AND HANDLING OF LAMPS — The photochemical lamps mentioned above are all standard types for which ballasts, transformers and sockets are generally available. All that is required is to provide the proper transformer, connect it to the line and the lamp socket and then insert the lamp. There are, however, a few precautions that should be borne in mind.

First, the electrical system must be dry. Waterproof wiring and water-tight connections and fittings are generally recommended.

Second, all metal parts of the electrical circuit must be protected from corrosive fumes. All lamps have terminals or screw bases which must make good contact in the sockets or the parts will overheat and fail. If possible, these parts should operate in clean air. If this is not possible, they should be cleaned frequently and, in some cases it may be necessary to enclose them completely in rubber or a similar protective material to guard against damage by corrosion.

Third, the lamps must be handled with reasonable care. They should be operated on transformers designed for them. They should not be overheated. In most chemical operations, the enclosure does not run hotter than an ordinary enclosed lighting fixture which often runs almost hot enough to boil water. Where the lamp is surrounded with air at high temperature, however, some special cooling may be needed. The single tube type of lamp needs special care. At full operating temperature the glass tube is almost red hot and will crack if splashed with water. In handling, care should be taken to keep the arc tube clean. Grease from the fingers bakes in it and may develop a weak spot in the tube.

All this knowledge has helped photochemistry come into its own. Powerful, efficient, long-lived lamps are ready at hand with simple, dependable auxiliary apparatus to operate them. During recent years knowledge of the many uses of radiant energy to catalyze or generate chemical action has been accumulating with rapidly accelerating speed. One of the most important new forces in the field of chemistry is electromagnetic radiation for tomorrow's new, better and cheaper chemical products.



Left to right, beakers show the progress of a toluene-chlorine reaction in one, two, three and four minute exposures. The radiant energy from the 3,000-watt photochemical lamp overhead accelerates the reaction to 10,000 times the normal speed in total darkness

WHAT TO LOOK FOR IN FM

Manufacturers Are Getting Into Large-Scale Production of Sets
First of Two Articles Appraising Their Necessary Qualities

By David F. Armstrong

WHILE post-war radio has not been all it was quacked up to be, FM and Television are two significant developments on the horizon. Television is still in its early stages of development and is so expensive as to be in the luxury class, but FM is now coming into its own. One large-scale dealer is now advertising a portable model FM-AM receiver for $54.95, which brings this kind of radio reception down to the prices the average man can afford to pay for this superior kind of radio reception.

A person who is interested in an FM radio should consider such a purchase only if he lives in an area served by an FM transmitter. There is a definite limit to the distance over which FM signals can be satisfactorily received. If you have any doubt as to whether your area is served, or is likely to be served, by an FM station, the Federal Communications Commission, Washington, D. C., will send you a list of stations and their locations. This picture is becoming brighter all the time. Former Chairman Charles Denny of the FCC predicted that there may be as many as 700 FM transmitting stations by the end of 1947. This will lead to a public demand for FM receivers and the Klondike in FM will be on.

In November of 1935 Major Edwin H. Armstrong announced the development of Frequency Modulation to the radio world. It was the end result of ten years of research and experiment to develop a system of radio communication in which a sending station would impress upon a radio carrier wave an electrical characteristic not present in static, and in which the radio receiver would eliminate the reception of all electrical impulses except the particular electrical characteristic the FM system was designed to accommodate.

To use the words of the inventor of the system: "In the course of years of experiments I discovered that there was one wave characteristic not found in natural and man-made disturbances—the wide frequency swing. It was that which led me to the basic FM invention, the essentials of which are a transmitter that will produce this characteristic and a receiver that will respond to it and that will reject all minor frequency variations and all variations of amplitude."

Major Edwin H. Armstrong, inventor of FM

FM went through a long and arduous struggle for recognition in its early days. There were "five years of continuous effort to overcome those tangible forces which exist in every industry and which have their basis in the characteristic resistance of human nature to change." But the fight was finally won in May of 1940, when the FCC recognized FM as a definite radio service and assigned it the 42-50 megacycle band, subject to certain rules and standards.

During the war and until 1946 the FCC forbade manufacturers to produce FM receivers. Then there was a new FM band assignment, the 88-108 mega-

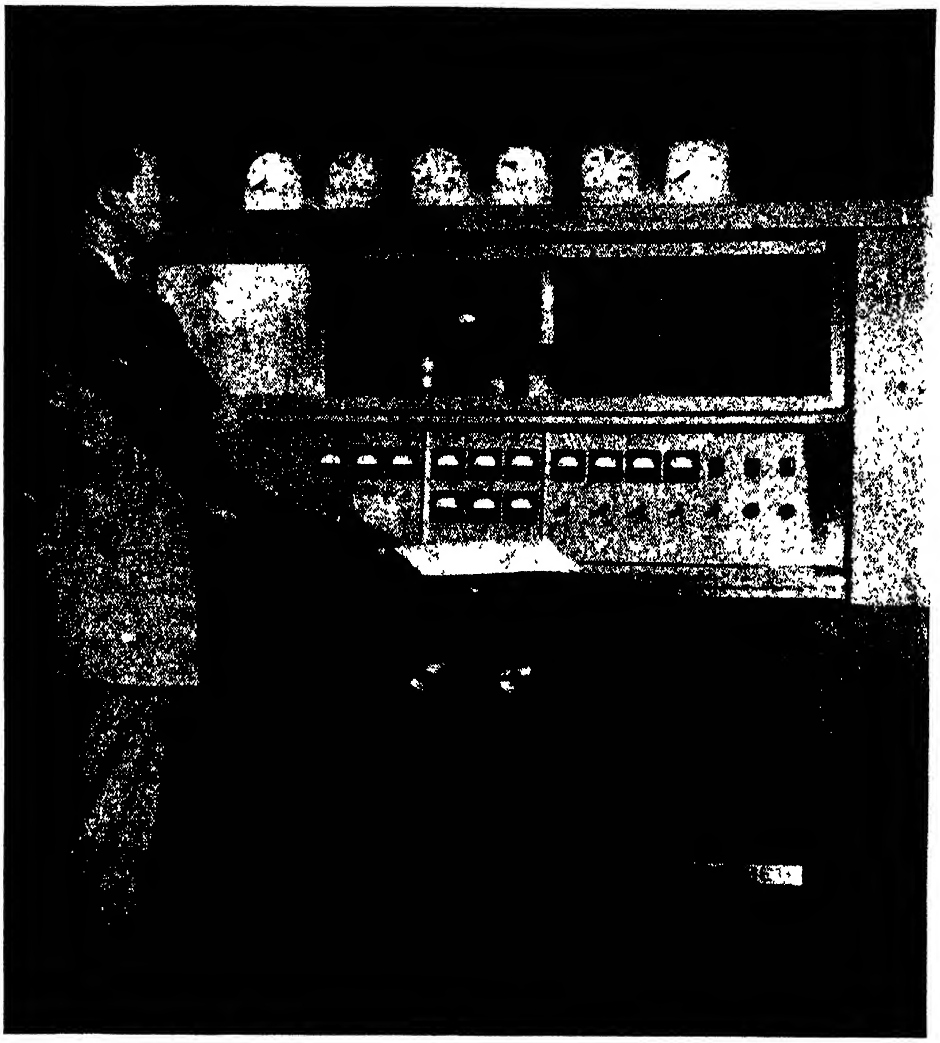
cycle band, which will eventually make the 42-50 megacycle band obsolete. Manufacturers were forbidden to make sets for both bands; it was either one or the other. But now there is a green light for the production of FM radios capable of receiving all the FM signals the FCC will permit to be transmitted in these two bands.

HIGHEST DEVELOPMENT — FM now stands as the highest development of radio communication. Transmitters and receivers are now available to serve the public with high fidelity, natural quality, and staticless reception in both music and voice programs. There is a misconception that FM is only for highbrow music lovers. Few beliefs could be farther from the truth. FM does improve the quality of music programs because it brings in the full liquid tones of the flute, the basso profundo of the 'cello and all the mellow cadences of the violin. It has the additional advantage of making the speaking voice more intelligible and sonorous to the individual who pays attention to intonation and innuendo. When you first hear the warm tones of genuine FM reception you will agree that the costly and complicated pioneering efforts that went into the engineering of FM are well worth while.

In the days of trying to sell AM radios no salesman liked to demonstrate a receiver during an electrical storm, but in selling an FM receiver the salesman welcomes the electrical storm because he knows it will offer concrete evidence of the ability of the FM receiver to eliminate static. The writer was present at a demonstration where the thunder accompanying the storm made the customers jump, but the music came in as clear as a bell. Again, FM is a real boon to dealers in areas where the AM band is so crowded that good reception is practically impossible. Here salesmen like to play FM and AM radios together to help the customer decide whether FM gives superior program reception.

Frequency Modulation is a serious challenge to the entire radio industry. It is now far beyond the theoretical and experimental stage and in time it may even make obsolete the radio programs based on Amplitude Modulation. But bear in mind that FM is high quality stuff. It is partly the responsibility of the manufacturers to make certain that the sterling advantages and the excellent quality of

A typical Frequency Modulation console model. This set contains both AM and FM receiving circuits and a record player with an automatic changer



Control panel of a Frequency Modulation transmitter. The large-face eye-level meters have pointers which move in recesses in the dial faces to eliminate the variations in readings due to parallax

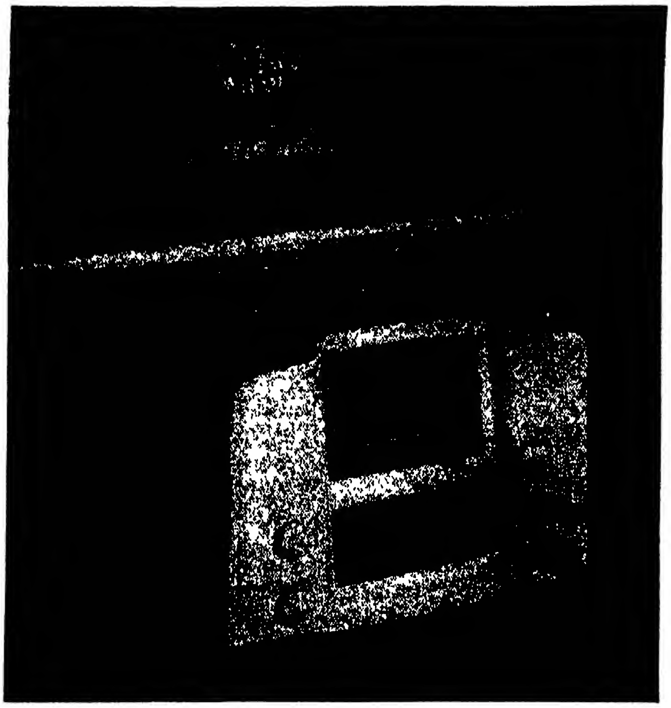
FM circuits are built into every piece of transmitting and receiving equipment sold. Human nature being what it is, it is also partly the responsibility of the purchaser to recognize the earmarks of the best quality so that he may purchase most wisely. Major Armstrong's comment on this point is significant: "FM has been pioneered, proved and is now in mass production. We have entered the FM era of radio. The public is entitled to the best from FM from the beginning."

DIFFICULT PROBLEMS — There have been some difficult problems to solve in connection with shifting the FM band from 42-50 megacycles to 88-108 megacycles. The necessity for redesigning sets and making experimental models to iron out the bugs at high frequencies plagued the manufacturers and slowed down production until very recently. Obviously the cost of all this design engineering will be borne by the present purchasers of FM. Later, when these costs have been absorbed, the price of FM can and will come down. The radio market has always been one of vigorous competition and FM will be no exception. At the present time there are about 30 leading radio companies licensed to build radio receiving sets in which the genuine Armstrong system of Frequency Modulation is utilized.

The production of FM receivers for 1947 is estimated at approximately 2,000,000. This compares very favorably with approximately 180,000 FM receivers for 1946. This has been achieved in spite of difficult engineering problems. FM-AM combinations are much more difficult to manufacture and assemble than either straight AM or straight FM. The combination jobs have more parts, the parts are more critical with respect to placement in the circuit, the permissible tolerances in FM components are small, the assembly operations are complex and the alinement of the completed receiver is a ticklish problem.

The extent of the FM manufacturing problem may be guessed from the confession of a vice president of one of our largest manufacturers. "It took bitter struggle over a period of many weeks to get 150 sets per day past inspection, and we were building three sets for every two we shipped . . . Today the same line . . . has no trouble knocking out 500 chassis a day of much higher quality than the early models. After more than a year we are doing the sort of job we thought we could do from the very first."

A short time ago one could say with conviction:



A table model AM-FM receiver. It is only recently that such models have come on the market

"It is conservative to estimate that the average retail price of 1947 FM receivers will approach $200, which is too high for the mass market. To the best of my knowledge, no manufacturer has yet begun to market any FM-AM set priced much below $100. We don't know how to build an acceptable FM portable, or an acceptable FM auto set."

Conditions change so rapidly in this industry that it is now becoming possible to produce table model FM receivers that have the same selectivity and sensitivity and tone quality as console models. If the circuit is carefully engineered and designed a table model can have just as much ability to limit static interference as a console model. The chief differences lie in those tone quality characteristics that depend on speaker size and the baffling of the speaker. These, of course, are limited in a table model.

FUNDAMENTALS OF FM — In any discussion of FM, it is valuable to review the principles upon which the system is based. Without becoming too technical, modulation refers to the changes that take place in a radio wave as it is made stronger or weaker when sound waves are converted into electrical impulses. If the frequency of the radio carrier wave remains constant and the height of the wave changes according to the variation of the voice or music sound waves, we have what is known as Amplitude Modulation (AM for short). This is the ordinary broadcast wave. It is also possible to transmit and receive sound waves by converting them into electrical impulses where the height of the wave does not change at all, but the frequency of the wave changes many times per second in accordance with the strength or weakness of the audio signal. This is Frequency Modulation, or, more commonly, FM.

People who bought FM receivers for the 42-50 megacycle band in 1939, 1940 and 1941 now have very few stations to listen to. There were 35 separate and distinct channels in the 42-50 magacycle band and this band is now obsolete. Stations now operating in the obsolete band may continue to transmit, but no new assignments will be made in it. It seems undesirable, therefore, to buy a receiver that includes this band.

In the new 88-108 megacycle band there is room for 100 channels. Each of these channels is 200 kilocycles wide (this is 20 times the width of the channels in the AM broadcast band, where the channels are only 10 kilocycles wide). These wide channels will eliminate station interference. Moreover, because of the short range over which an FM transmitter is effective, it is possible to duplicate channels and wave lengths all over the country. The FCC will probably permit this for stations which are located 200 miles or more apart.

The future in broadcasting probably lies with FM because of the general advantages of program reception and because of the economies possible in broadcasting. An FM station with an output of a few hundred watts has more power than an AM station of several thousand watts. The FM station does not require program monitoring to amplify low-volume sounds and flatten out the loud passages, it is free from static, it has a short range which eliminates station interference, it does not have a 5,000 or 6,000 cycle per second audio frequency cut-off and it reproduces the whole range of the sound spectrum from sixteen to 16,000 cycles per second with high fidelity.

From what has been said it should be clear to the layman that a receiver designed to receive AM signals will not receive FM signals. The average listener must therefore be concerned with the relative merits and drawbacks of each kind of radio program and how each affects his present radio use, his listening pleasure, his pocketbook and the next radio he has been thinking of buying.

Do not expect that *any* FM receiver will reproduce with all the fidelity sent out by a high-fidelity FM transmitter. Receivers vary in quality depending on the engineering skill that went into their design and construction. Moreover, not all FM broadcasts are high-fidelity programs. Some of them are "platter programs" and no greater fidelity will be transmitted from the station than was originally in the phonograph recording. But with FM a wide range of overtones can be reproduced with such remarkable clarity that the timbre of voice and music programs will be duplicated with extremely high fidelity.

The letters FM are coming more and more to mean: superior reception without static; elimination of all undesirable electrical interference; full dynamic range of tones for both music and speech; highest possible fidelity with minimum distortion; absence of background hum and noise with signals reproduced aganst a backdrop of silence. When the letters also mean Finest Made the listener is in for new auditory sensations.

Editor's Note: Mr. Armstrong's article will be concluded in the April issue of the Scientific American.

INVESTMENT CASTING

An Ancient Technology, In Which the Hardest Metals Are Poured Accurately in Ceramic Molds, Is a Growing Modern Business

By Edwin Laird Cady

EARLY in the war a need was found for parts made of metals which could not be forged, machined or cast on a production line by any ordinary method. A desperate search for means to make these parts was instituted. The trail led straight to precision investment casting.

Precision investment casting is a new process which has roots deep in the past. Hundreds, if not thousands, of years ago men realized that an object could be made of wax and the wax surrounded or "invested" with a ceramic material which would harden like concrete. The wax could then be melted and volatilized out of the ceramic investment and the cavity thus produced used as a mold for casting metal. For a long time the wax replicas and the resulting castings were made one at a time. Then, a few years ago, a method was found to mold the wax so many pieces and castings could be made from one model.

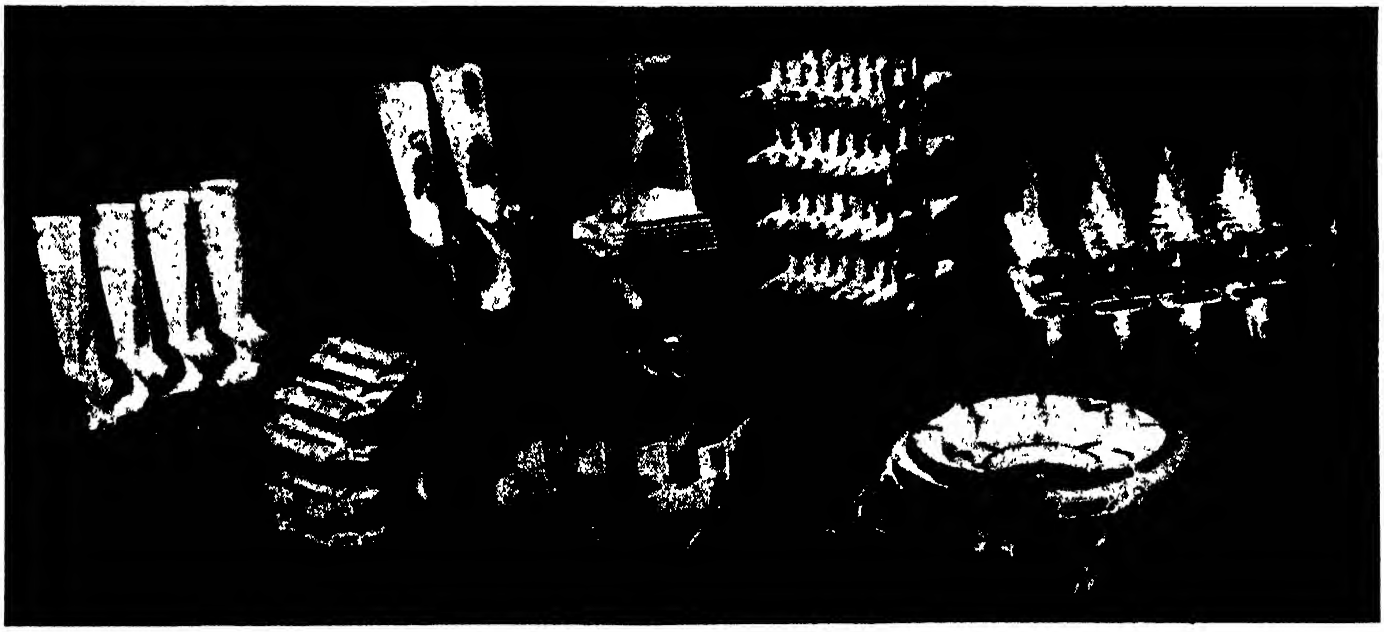
This step changed an ancient art into a modern precision process. Before the war the process was in use mostly for jewelry and for dental and medical products. Then the war industries picked it up, thereby making the turbosupercharger, jet propulsion, the gas turbine, some developments of radar and other war products possible.

When peace arrived nearly every factory management and engineer who had used the process during the war determined to continue with it. The advantages were obvious. Sand casting could not handle all of the alloys usable in precision investment casting, and could not approach the accuracy of its control over metallurgical qualities and dimensions. Die casting might be better for large runs of parts which could be made of extremely low melting point alloys such as zinc or aluminum, but it could not touch an enormous field of metals with higher melting points.

MISCONCEPTIONS — There were, of course, misconceptions. One was that precision investment casting required very little operating capital. The truth is that it needs as much fixed and operating capital as any other metal fabricating process. Another was that it needed little skill or experience. Actually it needs more of more different kinds of technical knowledge than other processes. A third was that it could achieve almost its full precision at equal cost, in spite of the age-old industrial experience that accuracy is directly related to costs.

These false ideas about invested capital, engineering knowledge and cost might be construed as three strikes against the precision investment casting proc-

A group of precision cast parts ready to be cut from the sprues and runners



ess. As a matter of fact, nobody knows what the complete score is. But out of every 100 companies which went into the field before 1946 at least 85 had left before 1947. And the end of the casualty list is not yet.

In spite of this, precision investment casting is a growing, healthy and prosperous business. It has plenty of room for companies which follow its present trends and operate with wisdom.

One line of development is the casting of alloys which resist forging unless their temperature is held within a narrow range and are impossible to machine. These alloys are used in jet propulsion machinery, in gas turbines and for other extremely high-temperature, heavy-duty work. This line, however, may be followed only by shops which know all of the complex techniques of the process, have wide experience and specially trained metallurgists. Nearly all of the shops engaged in this work began it during the war when research funds were easy to obtain, and have continued with its development.

Cobalt alloys such as Stellite are easier to handle than the forge-resistant metals, but are by no means the easiest. They are precision investment cast very largely because they can be machined or ground only with great difficulty. If accurate and intricate contours can be obtained by casting, costs can be considerably reduced. Some parts made at low costs could not be made at any practical cost by other processes. But since precision investment casting is used principally to make parts with accurate contours, the greatest skill and experience are needed to operate successfully in this field.

SALES ENGINEERING — As the alloys used in precision investment casting become easier to machine, and perhaps easier to cast, sales engineering increases in importance. The application engineering service given by the casters of the unmachinable alloys to consumers involves mutual scratching of expert heads to solve extremely difficult problems by any means whatever. The sales engineering service on the less difficult alloys must provide a choice of the greatest economy in a field where there are many production methods available.

Stainless steels are examples of alloys which benefit by such sales engineering. There are only a few types of stainless steel which can be bought in any desired sizes of wrought forms (such as bars, sheets and tubes) in small quantities. The other types must be had in cast forms. For this reason a great many stainless steel precision investment castings are made.

Stainless steels of the more common types are "different" rather than "difficult" to machine. But this kind of machining may require a steadier flow of heavier power than many machine tools can supply. Some stainless steels, moreover, are difficult for any machine tool to handle at high production rates. Sales engineering must therefore consider the machine tools available in the shop of the castings consumer and the type of stainless steel to be machined. On these two factors a decision is made as to which contours of the finished piece should be generated by casting and which by machining.

If the decision is in favor of considerable machining, a type of stainless easier to machine but lower in corrosion resistance and in physical strength may be decided upon. If, however, more of the contours are to be cast to size and shape so that the cost of casting is higher, the stainless steel should be more shock-resistant, durable under abrasive wear, dampening to vibrations and resistant to corrosion.

Precision investment casting sales and application engineering thus must be capable of dealing with the economics of product design as well as with production problems. The engineering is made easier by the fact that alloy ingredients make very little difference in the cost of metal for this process, although the costs of casting are higher for some combinations than for others. Thus, given a metallurgist who knows his job, the ability of a precision investment casting

Small investment-cast pieces are being inspected for dimensional accuracy by means of a jig. With the investment casting process very close tolerances can be held

house to sell by means of sales and application engineering is excellent.

Monel metals, stainless steels and other highly durable alloys have been put by this sales engineering into parts for sewing machines, printing presses, fishing equipment, business machines, thousands of devices needing highly accurate, intricate parts.

WITH MACHINABLE ALLOYS — When alloys are quite easy to machine another factor in sales engineering becomes important. There is no problem common to sand casting which does not also exist for precision investment casting Shrinkage, warpage, hot spots, hot tears, segregations—all can add to casting costs. The usual expedients of fillets, ribs, gradual junctioning of thin with thick sections and mild radii rather than completely flat contours are useful solutions of these problems. Parting lines and needs for drafts are not so severe as in sand casting, but do appear as problems to the precision investment process.

In a highly machinable alloy these strategems can be used with the intention of machining the unwanted fillets or ribs from the casting, or of machining drafted contours or slightly curved ones to the desired straight line or other shapes. The cost of castings is greatly reduced thereby.

This balancing of casting costs against machining costs to obtain the highest value in finished products has enabled precision investment casting to make bronze, brass, beryllium copper, 1020 steel, gray iron and other machinable alloy parts for electrical, radio, surgical instruments and for many other uses.

One of the most interesting developments is the carving of single pieces of pattern material in order to make castings for tools, molds and experimental parts for machines. This appears to be a return to the old days before the process had been developed into a repetitive precision one. Actually there is little relation between the original use of pure beeswax and the modern hard waxes, the very hard and completely machinable plastics such as Lucite, the building-up of shapes by the use of modern adhesives and similar improved methods.

Dies are being precision investment cast for plastics molding, rubber molding, die casting and metal stamping. Tools and tool parts for metal cutting and for woodworking and similar operations are being cast. The development and experimental costs of thousands of products are being reduced

It is in the casting of alloys for which sales engineering can be most widely applied that precision investment casting is making its most rapid strides. These alloys, plus tools and experimental parts casting, offer the most practical opening for any company which wishes to enter this field.

Also inviting to the newcomer is the fact that firms which make pattern materials, investment materials, and the various production machines, have developed a high degree of sales and application engineering skill. Materials and equipment are becoming more standardized. But even with these advantages the "three strikes" must be avoided. Precision investment casting always will need adequate capital, know-how and common sense.

Risers are being attached to wax pieces to be used in the casting of parts for B-29 manifolds

INDUSTRIAL CONSULTANTS

The Laboratory Problems Which Are Involved In Practically All Manufacturing Processes Are Frequently Too Big For One Business To Handle Alone. Result: Foster D. Snell, Inc. Is Ready To Take On a Little of Everything

By D. H. Killeffer

HUNDREDS of dolls came back to the factory, bloated, their original beauty faded to an ashen gray—not in the least the lovely creatures that had gone out earlier to gladden the hearts of little girls. But the doll maker could find nothing wrong; the dolls seemed to suffer from some new and terrible doll disease.

High quality slate became scarce and expensive, and a maker of school blackboards and children's writing slates feared he would be put out of business by cheap, inferior substitutes.

A chemical manufacturer making several different kinds of synthetic resins learned that one of them might be good in a paint of the odorless, quick-drying, water emulsion type, but he had among his people no one who really knew what painters and paint makers want.

A technician counts and identifies microbes through the microscope

A department store manager planned to put out a wax polish under the store's own name, but could not choose between five different waxes offered him by as many manufacturers at different prices.

A shaving cream that had wide popularity suddenly began to come back to the maker. Complaint was that the stuff turned brown or even black in the tube when any jackass knows that shaving creams should be white. Yet the factory had done nothing at all different from its long habit.

A company had been buying large quantities of refined corn oil over a period of time and seemed likely to continue to do so. The manager found that the price of raw oil was so much lower than that of this particular grade of refined oil that he believed he could profitably buy the cheaper stuff and refine it himself, provided of course that he could find a suitable process and an engineer to design and install the equipment.

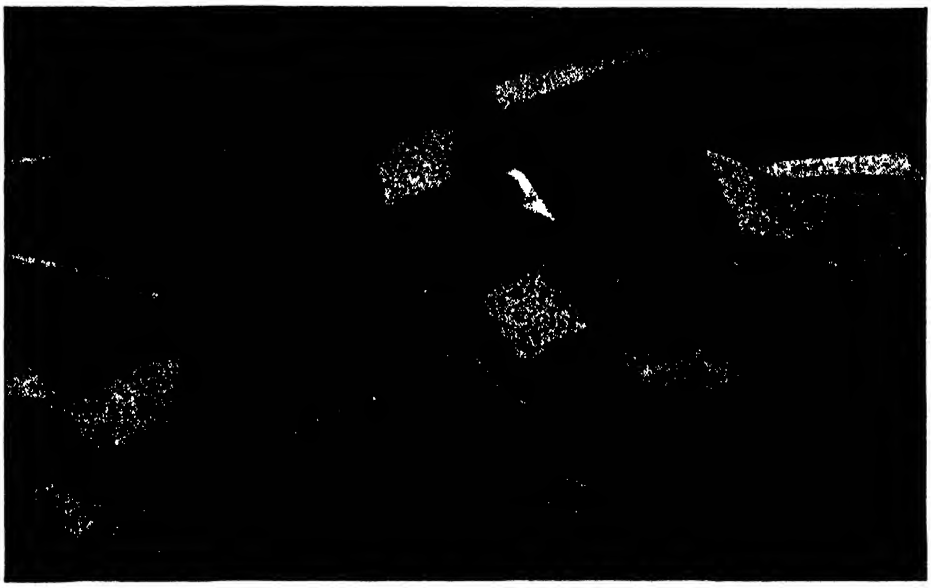
The waste of a manufacturing operation contained a small amount of acetic acid and the manager of the plant hoped that he could recover the acid and sell it. A survey of market and competitive conditions, a market research, gave him guidance to the proper answer: "No."

CHEMICAL CONSULTANT — A thousand problems like these continually plague the managers of businesses, large and small. They do not fit into any of the neat pigeon holes people usually set up to take care of their troubles and pass them on to a lawyer, a doctor, an auditor or a banker. They belong in quite a different class; and they can only fit if your set of pigeon holes includes one marked "Chemical Consultant."

Such people are becoming more and more useful in our world where science strides ahead, and where every bit we learn goes to work at once for all of us. Chemical consultants, both chemists and chemical engineers, give business and industry the benefit of our vast and growing store of scientific knowledge about materials. They turn dry scientific facts into solutions to industry's problems and they apply the scientific method of theory and experiment to find the answers to baffling questions of business. They often go further than that and discover, invent and develop entirely new phases of businesses—such as rayon, nylon, plastics and vitamins—that even change our habits and our ways of life.

Big business have so much use for this sort of thing that they save by maintaining their own staffs of scientists. These are well versed in the problems

The industrial consultant compares the interior structure of various loaves of bread with the standard during research on baking methods and materials



With this ingenious set-up the consultant measures the life expectancy of a toothbrush or the effectiveness of toothpaste

that a particular business is likely to have. They also know about the new directions it may take in growing. But at times strange problems, quite outside the company's usual ones, must be solved. Even the largest companies must go to someone outside who is expert at the particular problem in question. We have noted an example of this above: the large company which had skill in making resin but not in making paint. This problem was taken to a qualified chemical consulting group who had the required knowledge and ability. By coöperation, the manufacturer's scientists and the independent consultants solved the main problem and most of the lesser ones quickly and ably. Now the paint is ready to go to a paint maker who will soon supply it to all of us. It will be a radical innovation in paints. You will be able to paint a room or an apartment with it in the morning and occupy the space again in the afternoon without the disagreeable smell that usually clings for days to newly painted rooms. Because of this and because it can be used out-of-doors, the new paint will be handy for a great many uses. It may work a minor revolution in the painting of homes.

In contrast to this case, small businesses don't need scientists often enough to employ their own. They may not even know when a scientist could be useful. A great many try to get along without any

scientific help when they could use it profitably. This, of course, is a serious mistake when independent consultants are ready to help in the same manner as a lawyer or an accountant.

The problem of the deadly disease of the dolls that began this article was a problem of a small business. It was solved quickly and economically by a chemical consultant and the puzzled small business is now fast growing into a larger and prosperous one. The trouble turned out to be that the dolls were spoiled when the little girls who owned them lived in damp and humid regions. When the chemist found that out, it was a simple matter to change the formula for making the dolls heads to a composition that would not be injured by dampness.

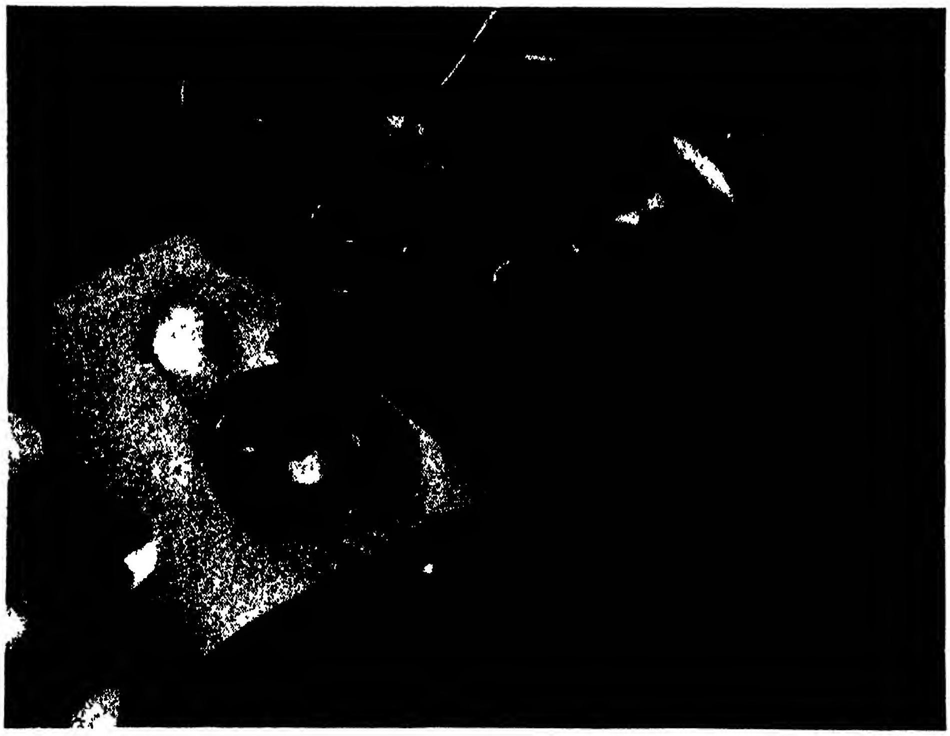
NEW KIND OF SLATE — The slate manufacturer saved his business much trouble, if not actual bankruptcy, by having an independent consultant develop for him a totally new kind of "slate." This was made by mixing fine sandy grains of a synthetic abrasive with molten glass so that the sheet glass product had a surface very like that of slate itself The rough surfaced glass developed to solve this problem actually possesses advantages never found in natural slate and is becoming an important commercial product.

Tests by a chemical consultant of the waxes offered the department store mentioned above showed that the best was not the most expensive, as the buyer feared, but that a wax at a lower price was actually better for the purpose than the more expensive ones.

The discolored shaving cream was a much harder nut to crack. Chemical analysis showed that the color came from the tin of the tube and some sulfur compound in the cream itself. But nothing going into the cream was different from the materials that had for years made white cream that stayed white! It would unduly prolong this story to no good purpose if we went through all the steps taken to track down the trouble. After much searching, the chemical consultant found that the maker of the alkali used in the cream had supplied its producer with what he thought was a better-than-usual grade of alkali. It was better alkali for most purposes but it was fatal for shaving cream in tin tubes. It seemed that a faint trace of free chlorine in the alkali had been neutralized by putting in a small amount of photographers' hypo. This had become a sulfur compound of a kind that would discolor tin and hence shaving cream in tin tubes. Once the trouble was traced to its cause, the remedy was simple: the old, lower grade alkali was used.

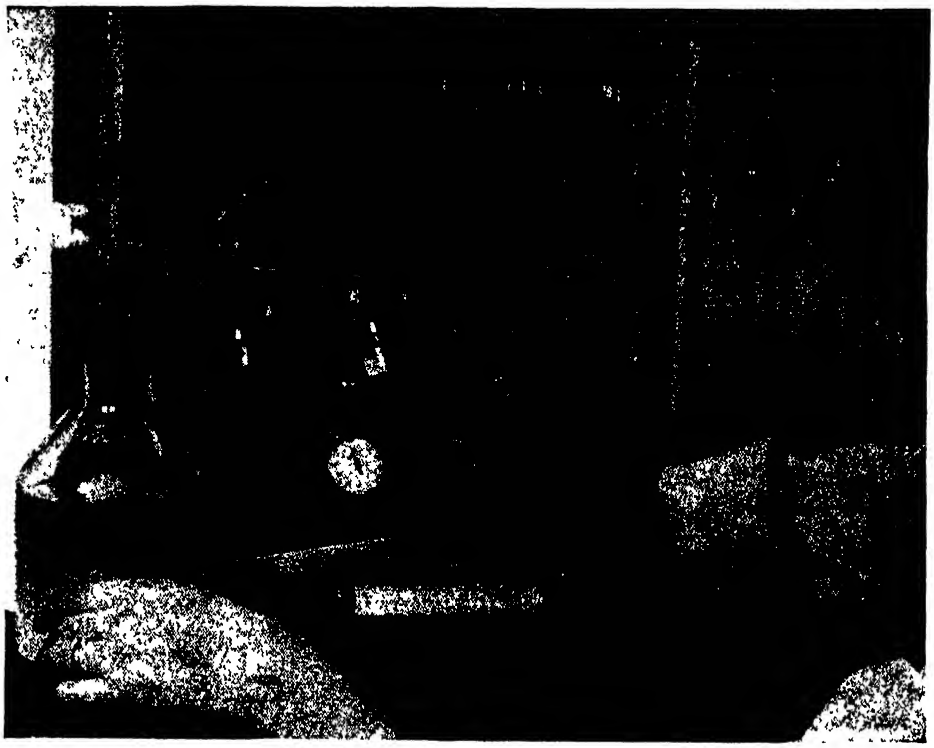
These instances show a variety of troubles which business men may meet and some of the ways to cure them. In every case the chemical consultant was able to find the cause and to suggest its remedy at a cost trivial compared with the loss which the trouble was causing the business. The basic fact is that independent consultants have the skill and equipment necessary to give business the benefit of science in a form fitted to business requirements. They are also prepared to do this at a cost that is economical for the services rendered.

A laboratory manned with skilled people and equipped with the apparatus they need to work effectively represents a major investment which is not to be undertaken lightly—especially when ready-made facilities exist to find out whether such an investment is economically practical. A company which feels it may have to establish a laboratory can make sure by going first to independent chemical consultants The consultants have a variety of services for every laboratory. Even independent consultants must limit themselves and cannot become



The Mullen tester. With this device the industrial consultant determines bursting strength, one of the most important of paper's physical characteristics

The industrial consultant performs many delicate chemical tests to evaluate the physical qualities of a great variety of substances. Here the stop watch reveals the hardness of a small sample of water



experts in everything. A look into the ten-story laboratory of Foster D. Snell, Inc., in midtown Manhattan, will suggest something of the character of consultation. This organization has grown up primarily by helping small businesses to solve their problems.

A laboratory such as this is a small business in itself. This one employs nearly a hundred people, most of them college graduates and specialists in some phase of the organization's work. It must therefore have the facilities usual for carrying on any business: offices, reception rooms, storerooms and the like.

MICROBE-FREE LABORATORY — It also must have several kinds of work rooms, each fitted and equipped for its particular job. One of the Snell laboratories, for instance, is devoted to bacteriology. The researchers went to great pains to design a special room for this purpose. They had to be certain that its walls, ceiling and floors were free from resident or floating microbes that might accidentally spoil tests. Nothing in the room can interfere with the bacteriologist's planned experiments. Even the air coming into the room must go through a filtering process to be sure that it carries with it no germs or dust from the outside.

The air in rooms set aside for tests of another kind is washed and treated for different reasons. When chemists want to calculate the strength of paper, for instance, they are careful to be certain of the exact temperature and humidity of the testing space. The reason for this is that they cannot account for the behavior of paper unless they consider these two important characteristics of weather at the same time. Everyone knows that even the size of a sheet of paper is larger when he measures it on a wet day than on a dry one. This is also true of the careful measurement of other values of paper, cellophane, rayon, and even many kinds of cloth. And this is the reason that one of the test rooms in the Snell laboratories has washed air pumped to it at painstakingly controlled temperature and humidity.

Another job for the consultant grows out of the chemist's need to call upon chemical engineers to make their laboratory experiments into factory processes. This means still another kind of work room, in itself a miniature factory Actually the chemical engineers who work in it are continually rebuilding and rearranging this pilot plant. As soon as they have learned the effect of one change in process or equipment, pilot plant operators have thought up another change to do the job better. At the Snell laboratories, this work room looks like a small-scale chemical plant. There is, however, one big difference: everything in the pilot plant can be quickly taken apart, moved about and put together again.

This is the kind of establishment where consultants mentioned earlier tried out the chemist's ideas about how to make a paint out of resin. Everything in the chemist's experiments was worked over in an effort to find how engineers could operate a full-scale plant to make the new paint. In running their tests in such a pilot plant they followed the classic advice of Leo H. Baekeland: "make mistakes on a small scale so you can make profits on a large one." This, then, is a necessary part of the work of chemical consultants.

A chemical consultant must also devote a good part of his time to chemical analysis and physical measurement. These two services are basic to the solution of almost any problem. They make it possible for investigators to get back of surface appearances to the real facts about materials Analysis not only detects impurities, like the sulfur in the shaving cream

mentioned before, but it often gives the expert an indication of the way a product was made, and how and where to look for the source of any trouble with it. Physical tests are designed to measure, for purposes of comparison, the properties—strength, gloss (as with the floor waxes we mentioned), life in service, and others—which relate to the value and life of the product being studied.

SURFACE PHENOMENA EXPERTS — Besides these quite general activities, each consulting group has its own specialty at which it is particularly expert. At Foster D. Snell, Inc., for instance, a special field is what scientists call "surface phenomena" and "surface-active agents." We need not here try to define these terms exactly, but rather let us say roughly that they have to do with the ability of liquids (particularly water) to wet things such as other liquids. solids and even gases. The most familiar examples are: soap, which helps water wet and clean our bodies in spite of our natural thin oily film; such commodities as salad dressing and dough for baking where we must mix those two proverbially unmixable substances, oil (or shortening) and water; and many other materials and operations (like making the resin-water paint) where you must mix together in one product substances of quite different, even antagonistic, natures. This includes, of course, the paradoxical "wetter water" of the headlines and the equally paradoxical "soapless soaps."

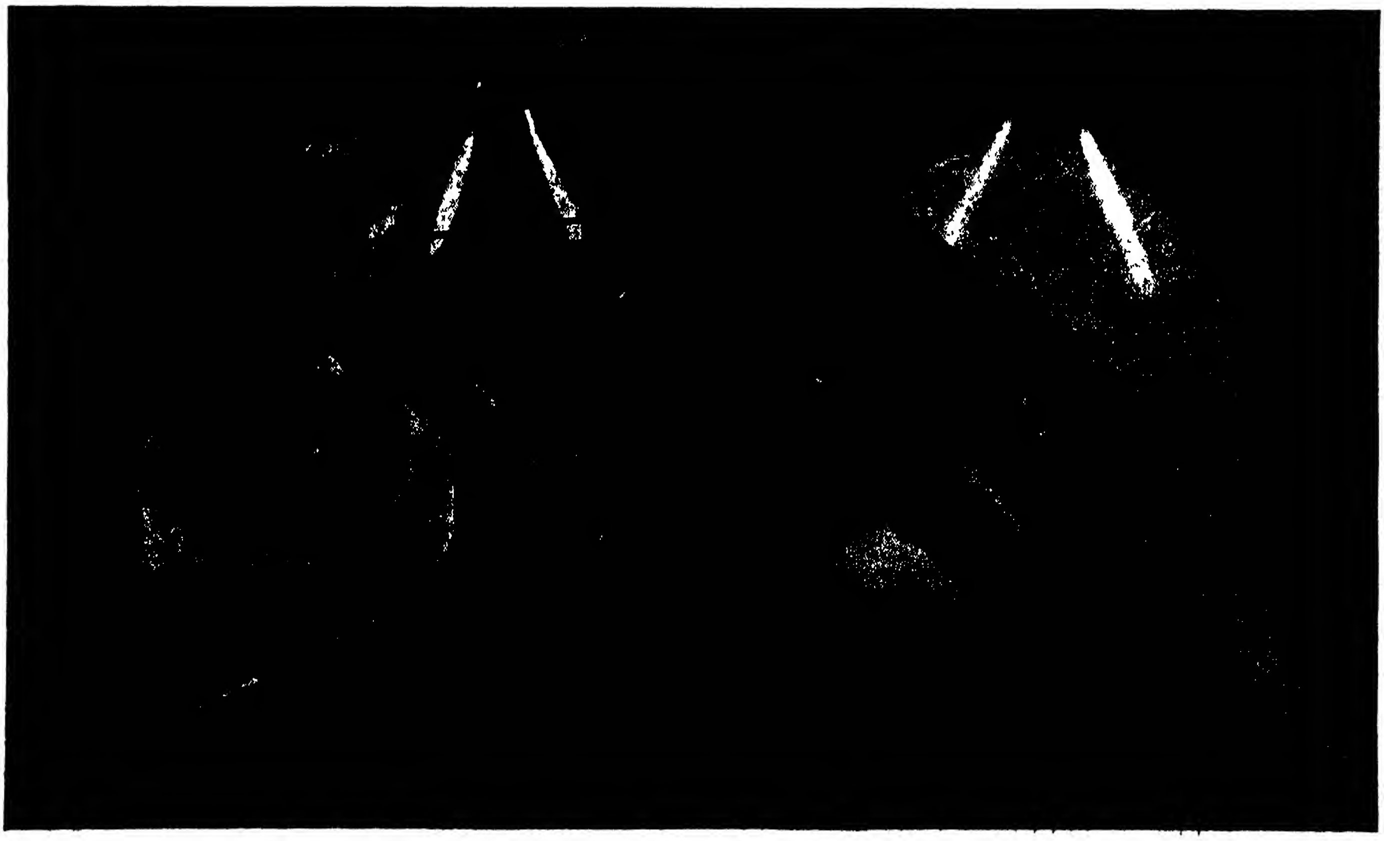
This work naturally spreads throughout all the ten floors of the Snell laboratory and into each of its departments. Here, for example, are washing machines that day in and day out work on small pieces of cloth that have been identically dirtied, called "standard soil." There is a great deal of difference between a washing machine and these launderometers, with their standard soil specimens in rows of glass jars mounted on rotating shafts. The job is the same, but the launderometer does it measurably and more accurately.

In another Snell laboratory, chemists measure the qualities of soap foam by blowing air through a solution in strangely shaped glass bulbs. A still different instrument (invented by Lecomte du Nouy, who wrote a current best seller "Human Destiny") measures surface tensions. This is the strength of the film which always surrounds liquids and which separates them from each other or from other substances. Researchers in surface activity are principally interested in controlling the strength or weakness of these films to suit their purposes.

Still other investigations in the laboratory seek improved ingredients for bakers to use in their dough and for compounders of plastics and rubber to include in their products. These researchers appear to casual observers as very different from the operations of the launderometer but actually all are a part of the same general problem: surface activity and its control.

From visiting the domain of a group of chemical consultants, one gets the impression that such consultants must know a lot about a great many different things. Above all they know how to solve the problems that vex all kinds of businesses, and how to do so economically. They give businesses a new but not untried kind of service to help keep them moving forward.

By measuring surface tension this instrument determines the strength of a soap bubble



SCIENTIFIC AMERICAN'S Industrial Digest

INDUSTRIAL ADHESIVES

Junctures Can Be Stronger Than The Joined Materials

INDUSTRIAL adhesives are rapidly reaching the point where they can join anything other than the strongest metals with junctures stronger than the materials themselves. The adhesive selection problem is becoming that of finding the one which will only slightly exceed the strengths of the joined materials and which can be applied with the greatest satisfaction at the lowest cost. Thus the adhesives industry which only a few years ago could hope to join only the weakest materials such as paper, leather and wood, is beginning to solve thousands of problems of the stronger materials. And 1948 seems destined to be the year in which industrial product designers begin most serious studies of what adhesives can do for them.

CARBIDE BORING BARS

Greater Accuracy and Efficiency At Reduced Cost is Reported

BORING bars made of solid cemented carbide are reported to be reducing costs, improving accuracy, increasing tool life and controlling surface finish in many production operations. The high degree of rigidity possessed by these carbide bars—2.8 times greater than that of steel—makes possible the precision boring of holes having a relative length up to eight times the hole diameter The greater stiffness of the carbide bars keeps the boring tools from backing away from the work, and prevents the bars from "winding" up in the holes. In addition, the carbide absorbs and dampens vibration, resulting in longer tool life and better control of finish. Another benefit is that it enables the use of more wear-resistant grades of carbide for the actual cutting tool than is possible with the less rigid steel boring bars, thus still further increasing tool life.

These characteristics of cemented carbides have been effectively used, for instance, in designing—around such carbide boring bars—a new and completely automatic machine for the boring of wrist pin holes in cast aluminum pistons.

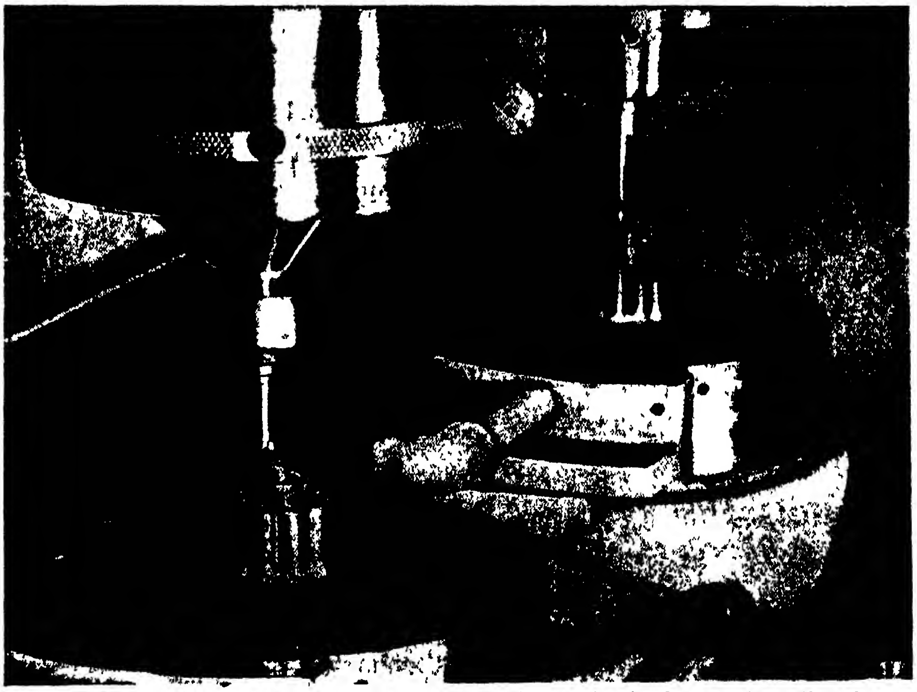
The total length of the hole in these particular pistons—that is, through both bosses—is 5.8 times the hole diameter. Formerly, it was necessary to drill the holes and then precision bore on double-end multiple spindle machines. Carboloy cemented carbide boring bars now permit "through" boring from one side only. Spindle and tool maintenance have been reduced by 50 per cent over methods used in the past.

The machine, of two spindle design, turns out 288 pistons an hour and approximately 2,300 per eight-hour shift. Cutting speed is 980 feet per minute. Floor to floor time is 25 seconds for every two pistons. The ability of the combination of carbide bar and carbide tool to hold size and surface finish over long runs has eliminated time lost in tool change shut-downs.

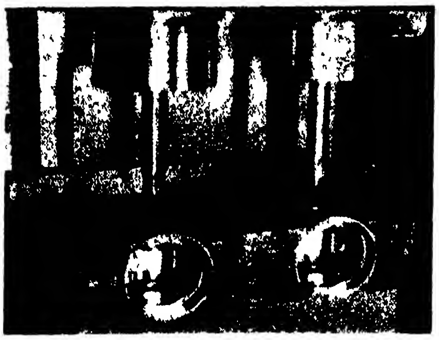
There was no change made in the grade of carbide used as a cutting tool.

Another typical application of the Carboloy boring bar is the boring of cast iron automotive valve guides having a ratio of length of bore to bore diameter of 7.3 to 1. Former practice was to drill, ream and "bearingize" the cast blank, following which the outside diameter was ground concentric with the hole. These holes are now bored in one pass (the out pass) with a solid carbide boring bar. Holes are straight, round and concentric with the outside diameter to a tolerance of .0002 inch. The operation has been in production for some months and has consistently produced 2,400 guides per eight-hour day. Tool life is between 12,000 and 18,000 bored pieces per grind.

Another manufacturer was experiencing difficulty in holding a .0002 inch tolerance when boring 3/16 inch cylinders in the bronze body of hydraulic pumps. The holes had a length-to-diameter ratio of 6 to 1. Primary cause of the trouble was chatter which resulted in tool failure, tapered holes, and excessive down time. This was due to a lack of sufficient torsional rigidity in the steel boring bars. A solid Carboloy cemented carbide boring bar, in-



Carbide boring bars in the two-spindle machine bore holes having length-to-diameter ratio of six to one in the hydraulic pump bodies, holding a .00005 inch tolerance



The carbide boring bars bore wrist pin holes in 288 aluminum pistons per hour

stalled in one spindle (finish boring) of the two-spindle machine solved the problem. The parts as inspected at the machine were consistently being held within a tolerance of .00005 inch.

Carbide boring bars are also being used to bore aircraft engine valve guides which are made of a bronze tube soldered on a nickel steel collar. When a steel bar was used, chatter caused rapid tool failure since the ratio of length to diameter of the bore is 5.5 to 1. Two cuts were made with the boring tool on each valve guide, after which the piece was pull-reamed to produce a hole that would pass inspection. To meet production schedules, two boring machines were used and two turret lathes were set up to perform the pull reaming. Some 45 pieces were produced per tool grind, and tool changes were made as often as six times per hour.

Using a solid Carboloy boring bar—shrunk into the spindle nose adapter of the boring machines—the holes are now being finish bored in one cut. The hole thus produced meets all inspections, including that for surface finish. Between 475 and 500 pieces per tool grind are now produced.

Consistent tool life can only be obtained by the duplication of the grind on the boring tool upon regrinding. This is particularly important in deep hole boring. Tool life may be quite erratic if care is not taken to duplicate the original grind.

The machine must be in condition in order to take advantage of the increased rigidity of the carbide bars. Spindles must be in good repair to use either a steel or a carbide bar.

ALCOHOL FROM ROSIN

Versatile New Material Is Commercially Available

Low-cost resin alcohol made from rosin has potential application in a wide number of industries including textile, rubber, adhesive, detergent, paint, varnish and lacquer. Called hydroabietyl alcohol, it is the first commercially available primary alcohol to be developed from rosin, one of the cheapest organic acids available. Hydroabietyl alcohol is a viscous liquid at room temperature. It is colorless, tacky and not miscible with water, in contrast to more commonly used alcohols. Of all rosin derivatives, it is the most resistant to discoloration and degradation by light or air.

The similarity of the properties of hydroabietyl alcohol to the properties of other high molecular weight alcohols, plus the fact that it is resinous in nature and low in cost, indicates a wide variety of industrial applications.

Like other high molecular weight primary alcohols it is subject to esterification with both organic and inorganic acids, and etherification. It is miscible with alcohols, ketones, esters, ethers, hydrocarbons and chlorinated hydrocarbons, and is compatible with many film-formers and resins used in protective coatings, adhesives and other products.

For many years the published research of laboratories both in America and Europe has disclosed a wide variety of valuable products that may be derived from hydroabietyl alcohol such as: resins, foamers, detergents, wetting agents, emulsifying agents, plasticizers, corrosion inhibitors, antioxidants, parasiticides, bactericides and compounds highly stable to ultra-violet light. Full investigation of these compounds has awaited the commercial availability of this unique resin alcohol.

Hydroabietyl alcohol can be used without further chemical reaction as a modifier for chlorinated rubber, polyamides, hydrogenated oils, textile sizers, rubber compositions and essential oil vehicles. Commercial production of hydroabietyl alcohol will be carried out by the Hercules Powder Company.

AIRCRAFT AUTOPILOT

Small Light-Weight Device Is Not Affected By Rapid Maneuvers

Unlike the majority of aircraft automatic pilot devices, a new midget autopilot recently developed by the Westinghouse Electric Corporation is virtually unaffected by rapid maneuvering or high rates of acceleration. Similar to the gyroscopic stabilizers used during the war for tank guns and airplane gun turrets, this midget pilot weighs only 35 pounds and will maintain control of a plane through loop-the-loops, barrel rolls, or great bursts of speed

Dr. Clinton R. Hanna, associate director of the Westinghouse Research Laboratories, revealed that the new autopilot already has been put through more than 3,000 miles of banks, turns, dives and level flight while the human pilot and engineers "sat by" as observers.

Describing the autopilot as "the speediest and most sensitive ever developed," Dr. Hanna declared:

"This unit is about half the size of most automatic pilot devices. It reacts to the human pilot's signal, or to unwanted motions of the plane, in one-tenth of a second, then flashes its message to the control mechanism even while such motion is just beginning to take effect.

"Even the biggest plane can be put through its paces by the twist of a knob on a small control box within easy reach of the pilot. To dive or climb, he merely moves the knob in or out; for turns, it is rotated right or left. In level flight, the pilot can sit back and relax while the plane flies itself."

The unflustered nature of the midget pilot suggests that such a device, radio-controlled, might serve to direct the flight of guided missiles and pilotless aircraft.

Source of its "mechanical composure," Dr. Hanna explained, is a compact metal case containing three spinning gyroscopes. These gyros, spinning at approximately 12,000 revolutions per minute, are "locked" to the plane and follow it during all maneuvers without any possibility of tumbling. They differ in this respect from the ordinary "position gyro" which is not locked to the plane and hence stubbornly resists any effort to change its direction of motion As a result, former gyros were sensitive only to changes in angle of the plane, whereas this midget pilot equipped with "rate gyros" responds both to changes in angle and to the rate at which such changes take place.

Although still considered to be "in the experimental stage," the midget pilot is expected to be applicable to light commercial and private planes as well as military craft.

CUMENE HYDROPEROXIDE

New Catalyst Makes Possible Cheaper, Better Rubber

Stronger and less expensive synthetic rubbers are promised by the development of a new chemical which can cut production time of rubber to 1/16 of that now required. In addition, the production of synthetic rubbers at temperatures as low as 40 degrees, F. is made pos-

sible by this material. Cumene hydroperoxide, as the new chemical is called, is a catalyst and is a development of the Hercules Powder Company of Wilmington, Delaware.

The great drop in production time made possible by cumene hydroperoxide will mean a considerable increase in plant output, not to speak of a lowering of production costs.

The chief advantage of manufacturing synthetic rubber at low temperatures lies in the fact that generally speaking, the lower the temperature during production, the stronger the rubber. Under present manufacturing methods, a temperature of approximately 122 degrees, F., must be employed, and the process stops at lower temperature.

The new chemical is being produced only on a pilot-plant scale so far, but it is expected that in the near future it will go into full-scale production.

A large number of other uses for the new chemical are foreseen. Laboratory tests indicate that cumene hydroperoxide will speed the production of many plastics.

Besides being less expensive than most peroxides, cumene hydroperoxide is safe to handle (as a rule, peroxides are unstable and often must be handled as carefully as explosives). This cuts shipping and storage expenses considerably.

UNDERPASS GEAR CUTTER

Curve Shaving Machine Ups Output With Less Operator Effort

Cast iron crankshaft timing gears are now being shaved at the Rouge Plant of the Ford Motor Company at a rate of 1,684 per eight-hour shift with less actual effort on the part of the operator who formerly shaved 920 gears in eight hours by the old method. This has been achieved by a combination of the use of the higher production "underpass" machines, as produced by Michigan Tool Company, Detroit, plus semi-automatic air-operated loading for the gears. With this combination, the operator is no longer required to load the gears on arbors and insert the arbors in the machine, and he is easily able to take care of the output of two "underpass" shavers.

The gear is simply placed on the fixture in the shaving machine, and a flick of an air valve control lever closes the fixture, thereby clamping the hobbed gear securely in place. The operator presses the start button to start the automatic underpass shaving cycle, then steps to the second machine to unload a finished gear and repeat the loading process there, while the first machine is completing its shaving cycle.

The former method required the operator to mount a hobbed gear on an arbor and also dismount the shaved gear from the arbor while the single shaving machine he was operating was completing its automatic cycle. Time was also lost and extra effort involved in mounting the arbor and gear between centers with the hand screw method that was customarily employed.

The Michigan underpass machines automatically crown all gears by "curve-shaving" them during the finishing process. This is made possible by having the reverse crown ground into the cutter.

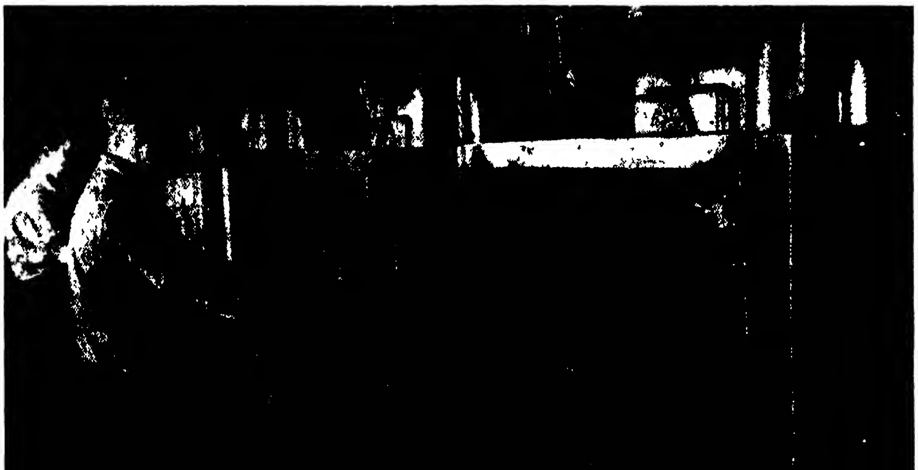
Average tool life with the underpass machines is 14,000 gears per sharpening. Since the shaving cutters, according to Ford, may be sharpened an average of seven times, total life per cutter including the initial 14,000 gears shaved before sharpening, is 112,000 gears.

The cast iron gear mounted, ready to start the underpass curve-shaving cycle

The cast iron crankshaft timing gears have a face width of one inch, 24 teeth, pitch diameter 3⅜ inches, and are eight diametral pitch. In clamping the gears in the fixture there is a slight amount of "backlash" between the green gear and the underpass shaving cutter, with the gear and cutter at crossed-axes to each other.

When the machine cycle is started, cutter and gear rotate in mesh, with the cutter driving the work. The cutter feeds tangentially beneath the gear until the gear is again in "backlash" with the cutter on the opposite side. Direction of rotation is then reversed and the cutter is fed tangentially back to its original position.

This method eliminates the upfeed plus a "rocking" motion frequently used on crowning shaving machines and is said to contribute both to the shortening of the time required for shaving and to increasing the life of the cutter since the wear is distributed across the entire face of the cutter. The cutting fluid used in the underpass shaving machines for these cast iron gears is kerosene.



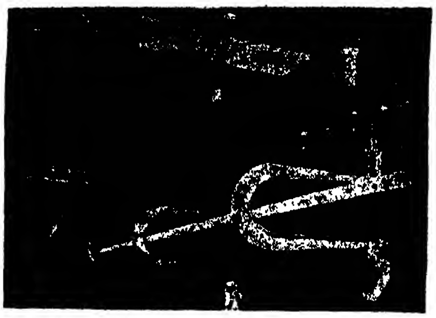
Two operators shave 3,368 gears in one eight-hour shift

DESCALING CONVEYOR CHAIN

Simple Power Brushing Set-Up Cuts Maintenance Costs

Designed to combat the scale which formed on a conveyor chain that passed through a rust-proofing solution, a novel power brushing arrangement has resulted in a substantial reduction in the cost of chain maintenance and has given the efficiency of the process a noticeable boost.

This brushing set-up which was installed in the refrigerator plant of the General Electric Company at Erie, Pennsylvania, operates in conjunction with the plant's new conveyor assembly. Two circular wire brush sections, 15 inches in diameter and containing .014 wire, are mounted on each side of the conveyor chain to contact it just after the chain emerges from the bonder-



Revolving brush cleans conveyor chain

izing bath. Not only does the brush clean off the scale deposits, but it also removes excess grease, oil and dirt which accumulate in regular service.

This plant's conveyor chain is one of the longest in service in this country and travels at the rate of 27 feet per minute. Prior to the introduction of the brushing method of descaling the chain, it was necessary to halt production periodically, remove the chain from the conveyor and clean it in a caustic solution.

One of the unusual features of this new brushing operation is that no special power mechanism is required to operate it. The brushes revolve with the chain, cleaning it continuously as the production line moves.

The installation was designed jointly by engineers of The Osborn Manufacturing Company, of Cleveland, and the General Electric Company.

COLOR MICROSCOPY

Particles Viewed in Various Colors Without the Use of Dies

Microscopy in color, without the use of dyes or light filters, has become a reality with a new microscopy technique. Developed by Germain C. Crossmon, Bausch and Lomb Optical Company scientists, this new technique. provides a speedier, more accurate identification of a wide range of colorless, transparent substances, including drugs and minerals. Dr. Crossmon terms the technique "dispersion staining." Only standard microscope equipment is required to turn transparent, colorless objects to bright colors. By choice of the correct immersion liquid which is placed over the sample, each different material appears a different color.

The method by which white light on a colorless object produces color is briefly this: The light from the microscope lamp is passed through a dark-field substage lens to strike the sample at a high angle. The sample is covered with a high-dispersion liquid that matches the light-bending ability of different materials in the sample at different portions of the color spectrum. Each material then scatters some of the colors present in the white light into the microscope where they are seen by the observer while other colors pass directly through the sample at such a high angle that they do not enter the microscope.

The new technique is expected to increase use of the microscope in checking foods or drugs for adulteration or contamination, testing minerals or ores for impurities and textiles for fiber identification. Crime laboratories can be expected to try dispersion staining to decide if microscopic fragments of materials are identical. Its use is also foreseen in medical microscopy for studying the relative refractive index of body tissue structures.

Use of dyes to stain tissues or bacteria probably will not be supplanted, Dr. Crossmon states, in those cases where absorption of the dye is a specific chemical identification of the material.

SWARF ELIMINATED

Magnet Removes Metal Particles From Grinding, Cutting Oils

One of the major problems of metals cutting and grinding has been the swarf, or extremely fine metal particles inclusions which become entrained with cutting oils, grinding coolants and lubricating oils. The particles may be only of colloidal sizes, but since oils tend to hold particles in solution by peptization, they may be much larger than colloids. They pass through fine screens, refuse to settle out and are so small as to be work hardenable to the greatest abrasive hardnesses which metals of their alloys can assume. Therefore they can do rapid damage to tools and to machine parts.

Permanent magnet machines operate continuously to remove these particles and deliver clean oil to the work points. The first result is conserving of oil. But the important results are prevention of spoiled work, prolonging of tool lives and protection of machine bearings.—E.L.C.

PORTABLE PLANETARIUM

Small Instrument Reproduces Sky Over Any Part of Earth

A compact unit, three feet high and weighing about 25 pounds projects on any surface the images of all stars down to the fourth magnitude—most of those that can be seen with the naked eye. Constellations are immediately recognizable and the illusion of the sky may be reproduced as it appears from almost any location on the face of the earth.

This portable planetarium turns on its polar axis at the rate of one revolution every four minutes. One complete revolution shows the rising and setting of the Sun, Moon, planets and stars.

The projection medium of this instrument is a dodecahedron housing composed of rigid sheets of the Bakelite Corporation's Vinylite. Each of these twelve sheets is punched with openings so that illumination, produced by a special bulb inside the housing, sifts through in proportion to the relative sizes of the stars and their position in forming the constellations.

Vinylite was chosen because it is non-warping and has maximum rigidity for minimum thickness, drills easily and cleanly, is easily cemented and stands vibration and occasional hard usage without denting and deformation.

The device was designed and developed by Armand Spitz, Director of Museum Education at Franklin Institute, Philadelphia, after a decade of experimentation.

Study aids, such as a light-pointer for directing attention to a particular star or constellation in a darkened room, and current star charts are furnished with each planetarium to assist users in demonstrations and teaching. Portable domes, which give the instrument greater fidelity of reproduction than it is possible to attain on a flat surface, are also available.

Auxiliary projectors showing constellations, coordinates, eclipses, cloud formations and other such phenomena can be used in connection with this new portable planetarium.

Armand Spitz with his planetarium

New Products

POWER RECORDER

Instrument Automatically Computes Engine's Total Power Output

To eliminate guess work in the measuring of engine usage and wear, a device called Power-Recorder, has been developed which records the cumulative power-hour units turned out by an engine, thus providing a measurement of total engine wear. This instrument promises to be of great value to all commercial airlines as a practical means for determining the time for servicing of the engines and thus increasing operating efficiency and economy in maintenance.

In aircraft engines the Power-Recorder, which is manufactured by the Square D Company, Elmhurst, New York, computes the total power-hours produced by continuously measuring the engine speed, manifold pressure and atmospheric pressure. Power data are obtained in accordance with the engine power curves for all throttle and propeller pitch settings and altitudes. The rate at which the power units are registered is directly in proportion to the power-hours delivered by the engine. The results are given in terms of equivalent hours at cruising power, thus registering 100 units per hour if the airplane is flown at normal cruising power.

Two types of Power-Recorders have been developed, one with a flexible shaft connection to the engine tachometer outlet, and another, a remote operating type which is electrically driven by a tachometer generator mounted on the engine tachometer outlet. For uses other than aircraft, the device can be calibrated in any convenient units, such as horsepower-hours.

The Power-Recorder prints the cumulative power units and the engine identification number in the manner of a timeclock so that the record can be filed for reference. It can also be supplied with a visual counter-type indication in the place of the printing mechanism.

DECADE SCALER

Self-Contained Unit Will Count Up To 130,000 Pulses per Second

Specifically designed for radioactivity measurements, a new decade scaler is a completely self-contained instrument. It has an input sensitivity of 0.25 volt and is equipped with three scale-of-ten counter decades, a four digit mechanical register, control for a clock timer and an adjustable high-voltage regulated power supply for the operation of Geiger-Mueller tubes.

The three plug-in counter decades are used to provide a convenient decimal scale registration of each count. A selector switch is provided for the selection of a scale of 10, 100 or 1,000 in driving the mechanical register located on the front panel. This decade scaler, which is a product of the Potter Instrument Company, Inc., Flushing, N.Y., will resolve two pulses which are five microseconds apart and will count continuously with absolute accuracy at rates up to 130,000 counts per second.

The high-voltage power supply is adjustable from 600 to 1,500 volts. The simplest circuits are used throughout the instrument, and it is claimed that it requires absolutely no adjustments.

ELECTRON DIFFRACTION INSTRUMENT

Pattern On Photographic Plate Aids Study of Surfaces and Films

A new research tool designed to aid in the observation and measurement of surface conditions of metals, ceramics and plastics, is valuable in the investigation of problems associated with corrosion, catalysts, lubricants, metallurgy, pigments and surface deposits. This electron diffraction instrument, as it is called, differs from the X-ray diffraction instrument, which analyzes thick specimens, in that the new instrument shows the crystal structure of surfaces and thin specimens to 500 Angstroms.

To operate, a beam of electrons is directed at the specimen being tested, and any resulting diffraction pattern is photographed. The pattern consists of rings whose diameter, intensity and orientation provide information for determining composition, orientation and size of the crystals present.

The instrument, which is a development of the General Electric Company's General Engineering and Consulting Laboratory, Schenectady, New York, consists of one unit containing vacuum chamber with specimen manipulator, visual and photographic recording camera, electron gun and beam focusing elements, regulated high-voltage power supply, and complete vacuum pumping equipment.

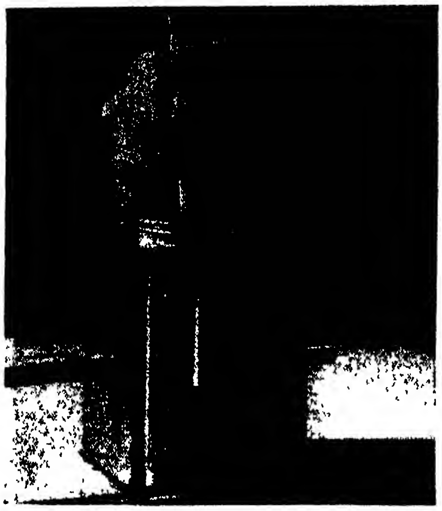
The specimen chamber permits examination of specimens ranging from 0.1 to four inches in diameter. In many cases, the instrument will detect and help identify the very first chemical changes before they are visible under a microscope or are otherwise detectable.

DEWPOINT APPARATUS

Moisture Content of Gases Is Easily And Accurately Measured

A new dewpoint apparatus is intended to meet the need in industry and in research for an inexpensive device to measure the moisture content of gases at approximately atmospheric pressure. Results obtained with this new apparatus are said to compare satisfactorily with those obtained by more complicated and more costly

Reloading the camera of the Electron Diffraction Instrument



The apparatus determines dew points at temperatures as low as minus 76 degrees, C.

methods. In addition, this device, which is produced by the Pittsburgh Lectrodryer Corporation, Pittsburgh, Pennsylvania, is claimed to be less subject to error, particularly at dewpoints below zero degree, C., than are units operating on the wet and dry bulb principle.

This apparatus consists of an outer container with inlet and outlet connections and a window; an inner container with a highly polished outer surface that is visible through the window; and a thermometer.

In order to determine the dewpoint temperature of a gas, a small sample is passed through the outer container of the unit while a mixture of crushed dry ice and acetone is stirred in the inner container. The stirring is done with the thermometer. As the temperature drops as a result of the stirring, the polished surface of the inner compartment is closely observed through the glass window. At the first indication of dew or moisture on the polished surface of the inner container the temperature is read from the thermometer. This dewpoint temperature is a reasonably accurate indication of the moisture content of the gas or air under test. Use of the acetone and dry ice mixture makes possible the checking of dewpoints as low as —76 degress, C.

SHORT-HAUL CARRIER

Three Channel System Operates On Open Telephone Line

DESIGNED to answer the needs of many organizations requiring wire transmission facilities over lines of moderate length, a small, three-channel short-haul carrier has been developed which will operate an open telephone wire for distances up to 150 electrical miles. This system, which is designated FTR 9-H-1 by the manufacturer, the Federal Telephone and Radio Corporatiôn, Newark, New Jersey, occupies only seven inches of vertical rack space per channel and weighs only 35 pounds. The transformer, coils filters and capacitors are hermetically sealed and mounted on the rear of the panels. According to the manufacturer, the use of this system to extend communication facilities results in a very substantial saving over the cost of installing a new line on existing poles.

ELECTRIC CORD PLUG

Wire Enters at Side of Flat, Rubber-Covered Plug

REPRESENTING a departure from conventional electrical plugs, a new Neophrene-covered plug is so designed that the cord enters at the side rather than at the front. Thus when the plug is inserted in a baseboard socket, the cord keeps flush against the wall, eliminating much of the hazard and nuisance of loose, tangled wires. In addition, the plug itself is flat, extending barely a half inch from the outlet and

The plug is only a half-inch thick

so it is far less an obstacle than is the conventional plug.

This plug, which is designated Neoplug 100 by the manufacturer, Neoline, Inc., Los Angeles, California, is entirely encased in Neophrene and has no metal parts exposed. The plug will fit all standard electrical outlets and is available in standard colors.

MULTIPLE-LINE STAMP

Monotype Marks Several Lines of Copy In a Single Operation

FOR MULTIPLE straight-line stamping of letters and figures, a new device has been developed which can machine-stamp in a single operation complete instructions for the use of a tool, complete name plates and so forth. This versatile marker manufactured by New Method Steel Stamps, Inc., employs interchangeable type which is set in the marker's type holder just as type is set in a printing shop. Each individual piece of type is slotted so that the entire row of monotype and spacing slugs can be held in place with a flat locking pin

The retainer of the multiple-line type holder has a hardened steel anvil for the type to bottom against. The outer case of the retainer is of hardened and tempered tool steel for long service life even under severe operating conditions. All insert monotypes are hardened and then ground to a standard size and length for accurate alinement when the type is assembled in the holder.

The marker can be used in the regu-

The multi-line stamp can be used in regular marking machines or in punch presses

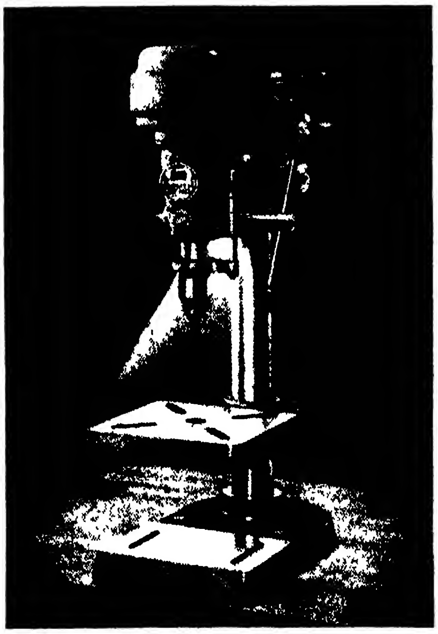
lation mechanical marking machines or in a variety of punch presses, and is available in various sizes and type capacities.

PRECISION DRILL PRESS

Tool Features Built-In Light and Simplified Speed Change

A NEW 14-inch precision drill press introduces several original features which add considerably to convenience and ease of operation. A built-in light with an independent switch provides shielded illumination for the work area, eliminating the necessity of installing a separate lighting fixture. A quick-acting belt tension release lever simplifies changing the spindle speeds and returns the vertical mounted motor to its original position after each change, thus maintaining the same belt tension for each of the four cone pulley steps.

The spindle has a maximum travel of four inches, with spindle speeds of 707, 1305, 2345 and 4322 revolutions per minute The free-floating spindle design prevents misalinement, side thrust and whip. The depth gage is graduated in sixteenths of an inch, and has adjustable collars to control both the depth of feed and the length of the return stroke. Two precision ball bearings carry the drive unit load and two



Built-in shielded light illuminates work

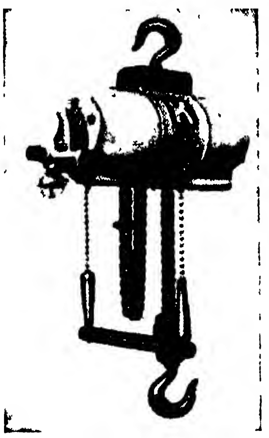
additional ball bearings carry the spindle, which is spline driven. All ball bearings, being pre-lubricated and sealed, require no oiling. The spindle quill bearing has adjustment to compensate for quill wear.

A full-tilt table, with 10 by 10 inch precision ground top surface, has slots for clamping fixtures or work. An improved type of double plug binder is provided for locking the table quickly and securely in any position on the 2¾ inch diameter column. Both bench and floor models are available. The drill press, a product of the South Bend Lathe Works, South Bend, Indiana, is supplied with or without motor, as desired. A 1/3 horsepower, 1725 revolutions per minute vertical mounting motor is recommended. An on-off switch, motor line connection cord, V-belt, motor pulley, and 0 to ½ inch capacity chucks are standard equipment.

AIR HOIST

Variable Speed Unit Has One-Ton Capacity

COMPACT and ruggedly built, a new air hoist having a capacity of 2,000 pounds features variable speed which gives the operator full control over po-



The speed of the air-powered chain hoist is variable from creep to 17 feet per minute. The entire hoist weighs only 75 pounds

sitioning, raising or lowering the load at any desired speed from creep to 17 feet per minute. The standard length of lift is eight feet. The hoist, designated Model 86-2V20 by the manufacturer, the Keller Tool Company of Grand Haven, Michigan, is equipped with safety stops. The roller chain is of high-grade alloy steel and swivel hooks are drop forged. The hoist is powered by a vertical piston air motor, and the entire unit weighs only 75 pounds.

BEARING CLEARANCE GAGE

Width of Flattened Plastic Gives Accurate Measurements

A QUICK and simple method of checking engine bearing clearances is reported from the Perfect Circle Corporation of Hagerstown, Indiana. With this technique a length of round extruded plastic is employed to give the measurements. This piece of plastic is packaged in an accurately graduated envelope. To check a bearing's clearance the bearing cap is removed and the piece of plastic is laid on the bearing shell. The bearing cap is then retightened on the crank, flattening the plastic. The cap is again removed and the width (not the thickness) of the flattened plastic is measured with the scale on the envelope. The clearance is read directly in thousandths of an inch.

HIGH-SENSITIVITY THERMOCOUPLE

Indicator Gives Accurate Reading In Hot Reducing Atmosphere

HIGHLY SENSITIVE, a new nickel-nickel molybdenum thermocouple will stay on calibration in reducing atmospheres at temperatures as high as 2100 degrees, F. Applications for the new thermocouple, product of the General Electric Company, include measuring temperatures in protective atmospheres in the heat-treating of steel and malleable iron, and in copper brazing.

The thermocouple element, supported by ceramic insulators, is sheathed in a special alloy protection tube which is welded at the hot end to make it air tight To assure rapid response it makes physical contact with the end of the tube. A special glass seal was developed to make the terminal end of the assembly air tight.

A gas-tight adapter is welded to the alloy tube at the terminal end. The adapter screws onto a one-inch pipe which is welded to the steel furnace casing to make a gas-tight connection with the furnace. Thus it is not necessary to pack the thermocouple or to use a junction box. The addition of a terminal connector with a die-cast housing completes the thermocouple assembly.

Before the thermocouple is assembled in the alloy tube, the nickel and nickel molybdenum wires are butt welded together, forming a strong joint that is free from foreign material. Standard chromel-alumel thermocouple extension lead wire is used for connecting the thermocouple to the temperature indicating instrument, as this wire matches the characteristics of the thermocouple.

SHEARCUTTING TOOL BIT

Molecular Cleavage Reduces Time And Cost of Production

OPERATING on the principle of molecular cleavage, a new pre-sharpened shearcutting tool bit is said to take cuts two to three times its normal size, thus greatly reducing production time and cost A product of Shearcut Tool Company, Los Angeles, California, this bit cuts metal with a knife-like action instead of chiselling it off by the common metal-rupturing method that is employed with conventional bits. Savings in production time of as much as 50 per cent, and savings in power consumption of over 70 per cent through the use of this new bit have been reported. Other advantages claimed for

Tool bit cuts by molecular cleavage

the new tool bit are faster cutting speed; less heat generated by the cutting action; and less wear on machine tools.

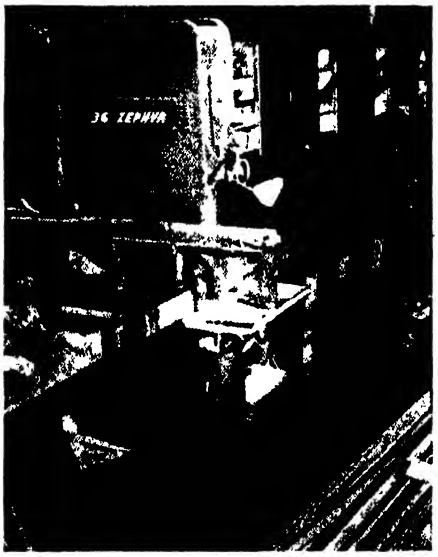
Precision tolerances may be held with the bit, and it is said that finishing cuts may often be eliminated. The tool may be used on copper, brass, bronze, plastics, cast iron, steel and other ferrous and non-ferrous alloys.

RESAWING MACHINE

Dual Purpose Unit Also Performs Regular Bandsaw Operations

A NEW COMPACT resawing machine features space and blade economy with accuracy and fine finish. This machine is designed for use by prefabricators, store fixtures, furniture, sash-door and other manufacturers who require special board sizes. With this new resaw, lumber can be purchased more economically by buying in odd lot sizes and then resawing to requirements. This further saves lumber storage space and enables a manufacturer to get a wide variety of wood sizes on short notice.

This unit, produced by the DoAll Company, Des Plaines, Illinois, is a



Resawing machine in operation

two-purpose high-speed band-sawing machine constructed especially for resawing but can be used for the usual band-sawing operations. The resaw mechanism, hinged to the machine column for quick positioning on the 36 inch square table, consists of a frame enclosing four sprocket and chain driven feed rollers, the one half horsepower drive motor and the variable speed unit. A spring tension adjustment accommodates variations up to a half inch in width of lumber passing through the rollers and a fixed scale with movable pointer insures positive dimension control of boards that can be cut from lumber up to 13½ by 15 inches.

The DoAll resaw achieves improved resawing efficiency by providing control of feed rate (10 to 60 feed per minute) with stepless variable speed drive. Balanced 36 inch drive wheels, automatic blade tensioning and heavy welded steel frame construction assures excellent blade life and vibrationless sawing accuracy.

Adjustable high-speed roller guides mounted above and below the table furnish the rigidity of back-up and blade control for accurate sawing—either straight ripping or for precision scroll work when the resaw carriage is swung aside off the table. The upper guide is mounted on a heavy post adjustable to height of material passing through the blade which is fully enclosed to point of work by a heavy steel telescoping guard for operator's safety. An automatic cut-off switch that shuts off the machine in case blade breaks is an additional protective feature.

The machine is sold fully equipped with 10 horsepower drive motor, blading and fixed speed selected for optimum sawing in either hard or soft woods. Regularly furnished with two-inch swaged tooth blade for top production, narrower buttress blades can be used in the interest of finer finish and less sawdust from high-grade lumber.

BRINELL TESTER

Machine Checks Hardness of Up To 800 Parts Per Hour

A BRINELL testing machine which is capable of checking up to 800 pieces per hour can test parts varying in diameter and thickness as much as ¾ inch without requiring adjustment of the elevating screw. This machine, a product of Steel Testing Machines, Inc., Detroit, Michigan, is identified as model KDR. It is motor driven and hydraulically operated. The tester is so constructed that it is impossible for the operator to remove the specimen being tested before the full load has been applied to the penetrator. The load is held for a predetermined length of time (adjustable from 2 to 15 seconds) after which the penetrator automatically reverses itself to starting position, ready for the next test. Specimens or parts which are of the same thickness or diameter—or within ¾ inch of that—are tested without moving the elevating screw with a resultant saving in time. This machine is equipped with a comparator indicator which eliminates the necessity of using the Brinell microscope on production testing. The machine can be furnished with a foot or knee starting switch. The throat opening is six inches and the maximum vertical opening is 14 inches. Standard equipment includes both flat and V-type anvils.

MIDGET POWER DRILL

Low-Cost Palm-Sized Electric Tool Is Announced

A LOW-COST midget power drill has been announced by Wolfson and Fairclough Manufacturing Company. This

Power drill takes bits up to ¼ inch

new device, called the King Midget Power Drill, is equipped with a geared-head motor, a trigger-finger control and it has a body of polished aluminum. The pistol-grip drill operates on standard 110-volt, 60 cycle A. C. at approximately 600 revolutions per minute, and takes bits up to ¼-inch.

DIELECTRIC HEATER

Simple, Low-Cost Unit Is Announced

FEATURING low cost and simplicity of operation, a new dielectric heater has been announced by the Radio Frequency Corporation of Boston, Massachusetts. This unit which operates at 30 megacycles per second, has no dials to set nor meters to watch. The inexpensive heater is applicable to drying, gluing and sealing operations and to the heating of metals and plastics. It is supplied complete with foot switch and electrode oven section, and a timing device is available as optional equipment.

ANGLE INDICATOR

Spirit Level Has Dial To Give Readings in Degrees

COMBINING a conventional bubble spirit level and an angle indicator, a new device called the Anglevel quickly determines slopes, pitches and inclines with a high degree of accuracy. In addition to four spirit vials (two vertical and two horizontal) the instrument is equipped with a dial indicator which is

The dial is calibrated in degrees

calibrated in degrees and gives an instant and exact reading of the angle being measured. The tool, a product of the R-D Company, Flint, Mich., has a frame of heat-treated aluminum and is 16 inches long 3 inches wide and ¾ inch thick. The entire unit weighs approximately one and one half pounds.

SINE WAVE CLIPPER

Test Signal Aids In Analysis Of Audio Distortion

A NEW sine wave clipper provides a test signal particularly useful in examining the frequency response and transients of audio circuits. Designed to be driven by an audio oscillator, the device provides a clipped sine wave. By feeding this output into the audio equipment under test, and in turn feeding the equipment's output into an oscilloscope, the servicer may quickly view and analyze distortion introduced by the amplifier. This sine wave clipper, a product of Barker and Williamson, Upper Darby, Pennsylvania, saves considerable time in engineering or repair work, since with the device the effect of making changes in the circuit may be seen instantly.

FIELD STRENGTH METER

Portable Unit Measures Output of Aircraft Radio Antennas

SIMPLE to operate, a self-contained field strength indicator is designed for instantaneous testing of the antenna output of aircraft radios. The portable unit weighs only one pound and consists of a small box and a telescoping antenna. Known as the Narco T-1, it

The portable field strength meter is completely self-contained and needs no external connections

contains a broad band untuned crystal detector coupled to an output meter measuring the relative power of transmission. It responds to all frequencies between 100 kilocycles and 150 megacycles making it possible to check antenna output on both low-frequency and VHF transmitters.

In operation, the Field Strength Indicator, manufactured by the National Aeronautical Corporation, is placed on any convenient external surface of the airplane whose transmitter is to be tested—normally on the cowling in front of the windshield so the mechanic can read output signals on the meter while operating the radio from the cockpit. The unit is particularly useful for tuning a transmitter for maximum output. The Narco test set is said to be one of the first made available which does not require batteries or an external connection of any kind.

HYDRAULIC LIFT TRUCK

Maneuverable Vehicle Eases Heavy Lifting and Stacking Operations

HAVING a capacity of 3000 pounds, a new hydraulic lift truck can simplify heavy, clumsy lifting, transporting and stacking operations. This truck, the latest addition to the line of hydraulic lift trucks produced by the Lyon-Raymond Corporation, is a mobile, easily operated unit that lifts and transports loads up to 3000 pounds. It may also be used to support heavy overhanging work and it can serve as a feeding table for heavy operations. The new truck simplifies and eases the handling and positioning of dies and other tools and fixtures, and it is a great aid in tiering skid loads and in the stacking of materials.

The forked tubular frame construction of the truck combines structural strength with light weight. Lifting power is furnished by a two-speed hydraulic hand pump which is mounted on the truck frame. A motorized pump that is powered by a ¾-horsepower motor can be furnished as optional equipment. The platform, which measures 30 by 36 inches, has a range of elevation of from six inches (lowered height) to 54 inches (maximum elevated height). The overall height of the uprights is 83 inches. The truck is equipped with two ten-inch front wheels and two five-inch rear wheels, all of which are equipped with roller bearings.

Lift truck supports up to 3,000 pounds

PACKAGED GENERATOR

Factory Assembled Unit Features Built-In Voltage Regulator

DESIGNED for use in engine-generator sets, a new packaged generator unit includes a revolving-field generator, a direct-connected exciter, an automatic voltage regulating circuit, meters and a selector switch for pre-setting the voltage. The only external connections needed for this compact, factory-assembled unit are leads to the generator switch. The built-in automatic voltage regulating circuit operates on the electrical resonance principle and has no moving parts. It requires virtually no maintenance and is designed to hold the terminal voltage to within 2 per cent of the selected voltage at any load or power factor within the generator rating.

The generator, which is a product of the Electric Machinery Manufacturing Company, Minneapolis, Minnesota, is available in standard voltages at popular 60-cycle ratings and with 0.8 power factor.

CURRENT BULLETIN BRIEFS

(The Editor will appreciate it if you will mention Scientific American when writing for any of the publications listed below)

CARBOLOY GENERAL TOOL CATALOG GT-200 supersedes Catalog 175R and its various supplements. Among the new products shown are solid boring bars; solid carbide face mill blades; solid carbide disks, disks with holes and solid carbide strips, and many others. An outstanding feature of the catalog is the 12-page section devoted to wear-resistance applications. Small line sketches show typical applications of standard carbide tools and suggested uses for various shapes of standard carbide blanks. Presented for the first time is a full-page chart showing where to use the various grades of Carboloy cemented carbide. Although Carboloy's line of standard single point cutting tools has not been changed, the tool order numbers have been changed to conform to the standards of the Carbide Industry Standards Committee. *Carboloy Company, Inc., Detroit 32, Michigan.—Gratis. 65 pages.*

THE ROMANCE OF NICKEL. This new brochure traces the history of nickel through the ages and describes the methods by which the ore is wrested from the earth and smelted and refined into usable metal. The research surrounding these uses and how such research is being applied to the development of future applications are described. Included is a general listing of alloys using nickel and other metals, as well as chapters detailing present uses of nickel and how these uses were developed. *The International Nickel Company, 67 Wall Street, New York 5, N. Y.—Gratis. 60 pages.*

PLATING BARRELS—MERCIL TYPE. Bulletin PB 107. This catalog covers a wide range of plating barrels, from the small single-unit jewelers' apparatus to the large multiple-unit production installations. New developments include a pumping apparatus for circulating the solutions, Merlon cylinders for resistance to a variety of solutions, and the new sizes of barrels for which are given inside measurements as well as styles having outside measurements. *Hanson-Van Winkle-Munning Company, Matawan, New Jersey.—Gratis. 17 pages.*

SUCCESS WITHOUT SOIL. A practical easy-to-read manual on Hydroponics, or soilless growing, makes it clear that it is not necessary to be a highly trained chemist to grow plants successfully without soil. Outlined are instructions on how to get started, the advantages of mixing one's own formulas vs. the use of prepared formulas, and the chances of success in commercial hydroponics. *The Chapman-Gilbert Company, Inc., 830 West Ivy Street, San Diego 1, Calif.—Gratis. 16 pages.*

ALLIS-CHALMERS PRE-ENGINEERED TEXROPE DRIVES. More than two-thirds of this new indexed catalog is devoted to a systematic listing of pre-engineered Texrope drives for all applications from one to 150 horsepower. Indicated are motor speeds, ratios and driven speeds according to horsepower. Where it is possible to fulfill the requirements of a drive from stock sheaves and belts, the most economical and best drive from an engineering standpoint can be easily and quickly selected from the new catalog. New pitch diameter sizes of B and C Magic-Grip sheaves are used in many of these drives, greatly increasing stock drive selection possibilities. *Allis-Chalmers Manufacturing Company, Milwaukee 1, Wisconsin.—Gratis. 144 pages.*

RAYON MILE BY MILE . . . PERFECT INCH BY INCH. Depicts and explains the Continuous Process whereby rayon yarn is spun, washed, bleached, treated, dried and twisted as a single thread in one continuous sequence of operations. The booklet is illustrated with photos and flow charts. Textile and tire production scenes are included showing how inch by inch perfection means better production in plants using continuous process yarn and tire cord. *Industrial Rayon Corporation. 500 Fifth Avenue, New York, N. Y.—Gratis. 24 pages.*

HEATING FOR METALS. The equipment and the processes illustrated and described in this bulletin apply to every step in the processing of metals from the time the ingot solidifies until the final operation is completed on the finished piece. Covered are one-way fired soaking pits; slab and billet heaters; normalizing and annealing furnaces and covers; furnaces and atmospheres; direct-fired production heat-treat furnaces; standard rated furnaces; inspirating systems and burner equipment. The bulletin also discusses in detail the science of gas chemistry for heat treatment. *Surface Combustion Corporation, Toledo 1, Ohio.—Gratis. 31 pages.*

HOW TO RUN A LATHE. 45th edition includes changes in text and illustrations since 1944 edition. The book covers the operation of the lathe units, grinding cutter bits, making accurate measurements, plain turning, chuck work, taper turning, boring, drilling, reaming, tapping, cutting screw threads, and so forth. Included are reference tables and over 365 illustrations. *South Bend Lathe Works, 388 East Madison Street, South Bend 22, Indiana.—Paper cover copies, $.25 postpaid; leatherette cover copies, $1.00 postpaid. 128 pages.*

LASTING PROTECTION FOR METAL SURFACES. This illustrated booklet presents comprehensive data on Dum Dum, the new tough but pliable and elastic water-repellent coating that protects metal structures against deterioration due to outdoor exposure. Properites, advantages, typical uses and application directions are included. *The Arco Company, 8301 Bessemer Avenue, Cleveland 4, Ohio.—Gratis. 12 pages.*

Books

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CALCIUM AND PHOSPHORUS IN FOODS AND NUTRITION

By Henry C. Sherman

A BOOK by Sherman on any aspect of nutrition is an event, but one on the role of calcium and phosphorus possesses great significance since these two elements have received his special attention throughout a long and active life. In the present volume, the essential material on this subject (single from a nutritional viewpoint) is condensed in 115 pages. This material is amplified by a sixty-five page bibliography of selected items noted only by full titles. Every student of nutrition will necessarily include this volume in his working library and its contents in his knowledge. The treatment is rather condensed and is unlikely to interest lay readers. (176 pages, 5 by 8½ inches) —$3.10 postpaid.—*D.H.K.*

THE HELICOPTER ADVENTURE

By Alexander Klemin

DR. KLEMIN, long a contributing editor of Scientific American, has created a truly unusual book for young boys. This is the tale of a former Naval flyer and his younger brother who together buy a helicopter and establish the "Harding Brothers Helicopter Service." There follows a series of wonderful adventures in which the boys with their helicopter rescue men from a vessel stranded off the coast of Maine; fly to the aid of a forester over a roaring forest fire; photograph the crater of the Mexican volcano, Paricutin, from the air; and find gold in the wilds of Northwest Canada. How the boys escape the dangers to win fame and fortune makes a yarn that is custom-built for the adventure loving youngster. (216 pages, 5½ by 8½ inches, illustrated.)—$2.85 postpaid.—*N.H.U.*

MIND AND BODY: PSYCHOSOMATIC MEDICINE

By Dr. Flanders Dunbar

PSYCHOSOMATIC medicine is the area in which the interaction of the mind and body is involved. When an old-fashioned doctor tells you your ill is "only in your mind" he is correct. Yet, since your mind *is* a true part of you, and since the notion that may be in it is doing actual harm, the ill is after all as much a reality as a broken leg and calls for as serious a treatment. This book mainly contains case histories of people whose minds have injured their bodies, and makes very human reading. Lacking, however in enough interpretation of each case, as if the average lay reader were a psychiatrist, the book fails in contributing a deeper understanding of the people one lives with and regards as normal. To commit an illogical bull, most of us aren't. (263 pages, 5½ by 8½ inches, unillustrated.)—$3.60 postpaid.—*A.G.I.*

CHEMICAL PROCESS PRINCIPLES Part II—Thermodynamics

By Olaf A. Hougen and Kenneth M. Watson

PART TWO of the three part work, "Chemical Process Principles," this volume deals with the thermodynamic problems of the process industries, with emphasis on the practical methods of process design and analysis from a minimum of experimental data. New generalizations are presented for approximating thermodynamic properties from molecular structures. An advanced and comprehensive text. (804 pages, 6 by 8½ inches, with tables and graphs.) —$5.10 postpaid.—*N.H.U.*

HYDRAULIC MEASUREMENTS

By Herbert Addison
Second Edition

TEACHING hydraulics at Fuad I University, at Giza on the Nile, Egypt, Professor Addison has an unhampered perspective from which to write a handbook on the confused and contentious topic of measuring the flow of liquids. This is his second edition, with additions intended chiefly for the users of various sorts of liquid meters. The main trouble with hydraulic metering is that it is as much an art as a science, depending upon the experience and trustworthiness of the individual who does the measuring. That this factor of the personal must give way to complete objectivity becomes more and more essential as industry more and more adopts flow techniques in transmitting materials. It must do so despite the inescapable fact that most flow is turbulent. In reaching such goal this book is a useful milestone. (327 pages, 5½ by 8¾ inches, illustrated.)—$5.10 postpaid.—*M.W.*

VERTICAL FLIGHT

By Parlee C. Grose

A COLLECTION of interesting and highly readable articles on helicopters. Articles are entitled: Further Notes on the Problem of Vertical Flight; The Prime Functional Essentials of a Vertical-Flight Craft; Beedynamics; The Rotary Wing; and The Magnus-Effect Rotor Lift. (18 pages, 9½ by 12 inches, illustrated. Paper covers.)—$1.10 postpaid.—*N.H.U.*

PYROTECHNICS

By George W. Weingart

THIS second edition of Weingart's Pyrotechnics follows the pattern of the first, with some amplification. It is primarily an instruction book for the maker of fireworks of various kinds and it emphasizes the types of material that form the principal pieces of fireworks exhibitions. The instructions and recipes given are practical and to the point, but they are clearly intended for the professional and are not the kind of thing one would expect to do for pastime. The obvious dangers inherent in the handling of explosive and highly flammable materials require that these be kept out of the hands of the unqualified and the careless. Although the author emphasizes safety precautions, he is clearly not writing for the idly curious or the amateur, who are likely to endanger themselves as well as others if they undertake such matters. Military aspects of the subject are suppressed to give emphasis to decorative and amusing fireworks. (244 pages. 5½ by 8½ inches, illustrated.)—$7.10 postpaid.—*D.H.K.*

EARLY WORK OF WILLARD GIBBS IN APPLIED MECHANICS

Assembled by L. P. Wheeler, E. O. Waters and S. W. Dudley

THE FOUNDATION of modern physical chemistry and the great impetus to thermodynamics was Josiah Willard Gibbs' treatise *On the Equilibrium of Heterogeneous Substances*. That Gibbs (1839-1903) climbed to that apex of mathematical thinking from his early studies in applied mechanics is scarcely known. Indeed, his Ph.D. thesis is published for the first time in this small book. Its title: "On the Form of the Teeth of Wheels in Spur Gearing." While he was still a tutor at Yale he was granted (1866) a patent on an improved car break. His patent attorney was Munn & Co., publishers of the SCIENTIFIC

The Editors Recommend

Best Sellers in Science and Technology

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HIGH FREQUENCY INDUCTION HEATING — *By Frank W. Curtis.* Answers many questions concerning induction heating and its utility in industrial processes. Thoroughly practical in scope. **$3.10**

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for steam engines. But, according to Dr. Wheeler, one of the three compilers of this memorial, Gibbs lacked the money and time to exploit the device. (78 pages, 6¼ by 9½ inches, three illustrations.)—$3.10 postpaid.—*M.W.*

FLYING MINUTE MEN

By Robert E. Neprud

PEOPLE smiled at the Civil Air Patrol uniform with its curious red tabs, and thought its pronouncements flamboyant. If such people on the basis of these two minor elements thought the war work of CAP to be of little value, they were wrong. The CAP grew into a voluntary, yet well disciplined army of 100,000 civilians who, with little put-puts or Cubs, patroled our borders, discovered submarines, rescued airmen at sea and in many other ways made history and a name for themselves. Mr. Neprud has succeeded in setting down an accurate historic record and writing a fine, stirring, human story that will appeal to every American whether or not his interests lie primarily in aviation. (243 pages, illustrated with cartoons by Jack Mosley and photographs)—$3.10 postpaid.—*A.K.*

THE WATER-SOLUBLE GUMS

By C. L. Mantell

SINCE Biblical times great numbers of the water-soluble gums of trees and sea weeds have been important articles of commerce, and like many other ancient arts, this one is far ahead of its scientific treatment and explanation. Dr. Mantell has assembled in a single volume a great mass of information about the sources, preparation, characteristics and uses of these valuable and ancient materials. The breadth of the field is surprising to one accustomed to think of the water-insoluble resins as the principal products of plants. The broad uses of gum arabic are extended by such important commercial products as agar-agar, karaya, ghatti and the various lichen gums. The result is that the subject matter of this book goes into many diverse and apparently unrelated industrial fields: paper, cosmetics and foodstuffs, for instance. A valuable compendium. for instance. A valuable compendium.—(279 pages, 6 by 9 inches, illustrated.) —$6.10 postpaid.—*D.H.K.*

HIGH VACUA

By Swami Jnanananda

A NEW BOOK in this restricted field is an event. This one covers kinetic gas theory in high-vac work (74 pages); pumps, all types (78 pages); measurement of pressures nearly all types of gages (92 pages); high vac technique (28 pages); preparatory work (13 pages); physical chemical methods (13 pages). Written for other physicists—the author being at the University of Michigan—this book does not take the non-physicist by the hand and baby him through the difficult art. Yet anyone attempting high vacuum work will be many times its value behind the game.

If he does without its help, even though it is no more than 98 per cent up to date. The data are compact, systematically organized and the author's name as given is *not* a misprint. (310 pages, 5½ by 8½ inches, 134 illustrations).—$5.60 postpaid.—*A.G.I.*

FLAMEPROOFING TEXTILE FABRICS

Edited by Robert W. Little

One of the American Chemical Society's Monograph Series, this book contains contributions from some 17 men, all of whom were actively engaged in wartime research on the flameproofing of textiles. The book is divided into three parts—Fundamentals, Methods and Applications—and contains the result of the three years of research by the contributors. An excellent work, but one obviously designed for professional readership. (410 pages, 6½ by 9¼ inches, illustrated.)—$6.85 postpaid —*N.H.U.*

APPLIED ARCHITECTURAL ACOUSTICS

By Michael Rettinger

Based on geometrical rather than physical (wave) acoustics, this is a thoroughly practical handbook specifying the best size and shape for sound studios and motion picture theaters, together with data for insulative, absorptive and reflective materials and construction to reach the best acoustices in such enclosures. The author, a Hollywood engineer for the Radio Corporation of America, includes stimulating advice for maintaining good acoustics in churches and other large rooms, and for quieting noises in hospitals. (189 pages, 5¾ by 8¾ inches, charts and illustrations.)—$5.60 postpaid.—*M.W.*

FUNGI

By Wolf and Wolf

Readers searching for the right book on fungi should study the following wording closely. This is not your book if you are looking for a fieldbook on how to know the mushrooms from the toadstools; or how to identify fungi on the run; or for lively, entertaining reading; or for any kind of popular treatment. It may be your book if you have worked your way through books like the above and want something more solid, a textbook and reference for those who have already studied it (a poor reference for those who merely pick it up); if you don't seek the charm of nature writing; and if you want to be as nearly professional a mycologist as an amateur can be. For such it is a meaty work deserving of much respect. The illustrations are scientific, not decorative. (Two volumes, 438 plus 538 pages, 5½ by 8½ inches, 235 illustrations).—$12.70 postpaid.—*A.G.I.*

PLANTS AND ENVIRONMENT

By R. F. Daubenmire

Serious, studious readers willing to dig will get from this (or any) textbook of autecology (study of interrelations between plants and environment, subdivision of ecology) an appreciation of plant life utterly incomprehensible to a person not thus trained. Autecology is a study of those phases of geology, soils, climatology, zoology, chemistry, and physics relating to plant welfare. This is a young science making rapid headway today, though relatively few are aware it exists or of its deeply significant content. (424 pages, 5½ by 8¼ inches, 87 illustrations.)—$4.60 postpaid.—*A.G.I.*

YALE SCIENCE THE FIRST HUNDRED YEARS 1701-1801

By Louis W. McKeehan

Yale University is celebrating the centennial of its Sheffield Scientific School. This led Professor McKeehan to look into the teaching of science during Yale's own first hundred years. There was mighty little, and what there was was in the beginning merely by-play to the theological studies for which Yale was founded. As an epitome of how mankind's propensity to talk slowly gives way to skill in observation, this little book is a pleasant pocket piece. (82 pages, 5 by 7½ inches, two facsimiles.)—$2.60 postpaid.—*M.W.*

ELEMENTARY NUCLEAR THEORY

By H. A. Bethe

Selection of topics within the theory of atomic nuclei, treated in an elementary way—for physicists. Many others probably would not find it anything like elementary. Emphasis is on nuclear forces, the central problem of nuclear physics, and on beta disintegration. Author is a member of the Los Alamos Staff and professor of physics at Cornell. (147 pages, 5½ by 8¼ inches, 17 illustrations.)—$2.60 postpaid.—*A.G.I.*

ACHIEVEMENTS IN OPTICS

By A. Bouwers

Now it comes out that in Nazi-dominated Holland the author early in the war invented and with Dutch official connivance secretly patented a variety of telescope systems practically the same as those Maksutov published in 1944. A non-concentric system, a concentric system, a corrected concentric system, a mirror microscope, an improved Cassegrainian, a remarkable binocular, a very fast camera, a television projector, other uncommon things. On the basis of the evidence in this little book, the first 65 pages of which describe these things up to a point, some think the Maksutov telescope should now be called the Bouwers or Bouwers—Maksutov. Advanced amateur telescope makers will find the evidence of interest; beginners may flounder a little. Remainder of book pertains to diffraction and aberration researches of less interest to telescope makers. (135 pages, 5¾ by 6¼ inches, 64 illustrations, paper covers).—$2.60 postpaid.—*A.G.I.*

Telescoptics

A Monthly Department for the Amateur Telescope Maker

Conducted by ALBERT G. INGALLS

Editor of the Scientific American Books "Amateur Telescope Making" and "Amateur Telescope Making—Advanced"

IMAGINE yourself high aloft in the small round prime focus cage of the 200" telescope privileged to be present at the final climax of 20 years' effort when the mirror was given its first tests with a knife-edge and eyepiece in its mounting. Imagine the suspense! An air letter from Russell W. Porter:

"I'm just off Palomar Mountain and have had a look at the 200" mirror at the prime focus with a knife-edge, using a 9th magnitude zenith star as light source, a sight never to be forgotten. Its image was so bright and appeared so real that one felt he could take it with his fingers and feel it.

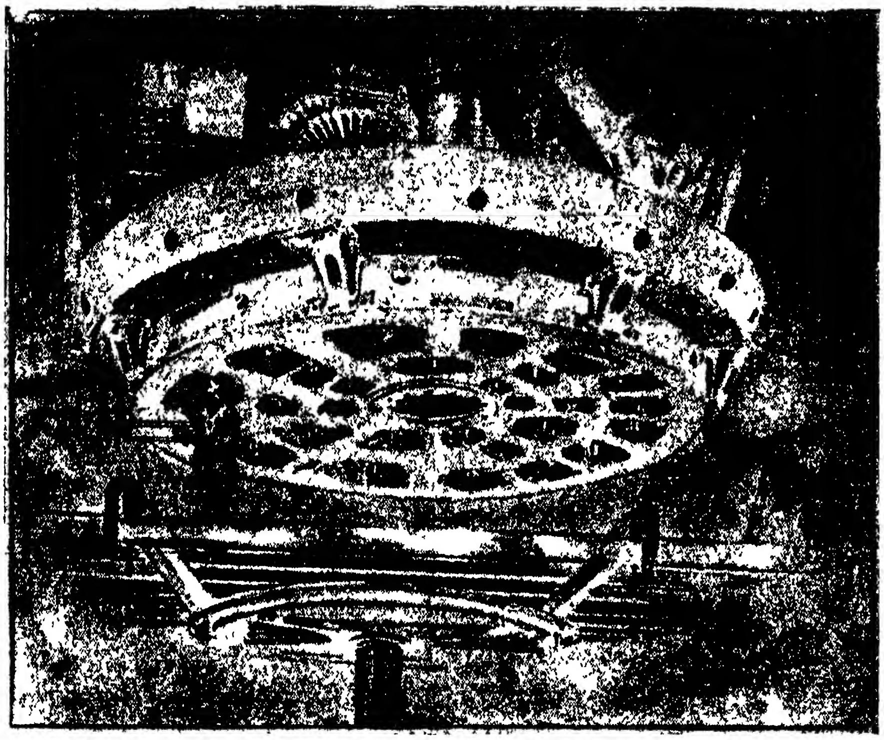
"This was the first time I had ever seen the Foucault shadows from a large mirror with light coming through our atmosphere from a star. The seeing was about 2 on a scale of 5 (so Humason estimated) and showed up remarkably the turbulence of our atmosphere. I would liken the appearance, when the star's light was about half cut off by the knife-edge, to reeds or eel grass in a rapidly flowing river, weaving back and forth in the stream. This shredded appearance of the atmosphere was thought by Dr. Anderson to have its origin about two miles up.

"Later in the night the seeing improved. *The Foucault shadow darkened uniformly all over the mirror with the cut-off from any direction.*

"With an eyepiece the image widened, inside and outside focus, in perfect circles.

"All the men who understand mirror testing—Bowen, Anderson, Hubble, Brown—were highly elated at the mirror's figure.

"The sketch I enclose was made the second day and shows the lower end of the telescope tube, looking up under the cell that supports the mirror. In the many openings at the bottom of the cell may be seen traces of the supporting levers. It was below freezing and this drawing was made in a hurry. After about an hour my hands got so cold I couldn't hold my pencil—poor ol' arctic explorer."



To telescope makers these results sing! Interpreted for others they mean:

As the mirror maker works he stops often to test, throwing on his mirror the light from a tiny illuminated pinhole in a distant screen (artificial star). The rays return to his eye and are examined (1) with a telescope eyepiece (low-power microscope) inside and outside focus (2) with the eye by skillfully cutting them with a knife-edge. The first gives qualitative overall tests, the second highly precise

quantitative tests of all areas. Finally the mirror is similarly tested in its telescope on an actual star. "Perfect circles" and "darkening uniformly" mean success. Astronomers celebrate with expansive grins.

Later information: The mirror tests satisfactorily in all positions.

Uncommon optical grinding and polishing materials is the subject of the following discussion by John M. Holeman, 305 Thayer Drive, Richland, Wash., continued from last month.

At present, the "Diamond Dust" sold by lapidary supply houses costs $2 a carat, but one carat is enough for quite a few experiments. This material is a by-product of the diamond cutting business and can be seen under the microscope to consist of white flakes of all sizes from powder to fairly large pieces. This is the cheapest way to buy diamond but, naturally, such a mixture cuts and polishes at the same time and leaves the work more or less scratched. To get the fastest cutting or to produce a smooth surface it is necessary to have the abrasive graded into at least coarse, medium, and polishing sizes.

In grading diamonds the larger pieces are broken up in an Abich mortar. These can be obtained from scientific supply stores or easily made after an illustration such as the one in Orford's "Lens Work for Amateurs." The reduced material is then levigated in the usual manner, except that oil is used instead of water. Of course it is impracticable to levigate a small amount, also the presence of the oil makes the whole thing very messy. Diamond dust is perhaps easier to buy prepared than to make. The Elgin National Watch Co., Aurora, Illinois, sell well-graded material mixed in a jelly for easy handling. Needless to say, the finer grades, which are comparable to rouge in particle size, are more expensive but will put a beautiful polish on diamonds, quartz, glass, Stellite, Carboloy, or almost any hard substance.

The following method was used for rapidly making several 1" diameter lenses from a very hard substance. By the process described it takes about two hours' total time to shape and polish one side of a lens having hardness 9.

First, however, before starting to use diamond the optical worker should be warned of diamond poisoning. If a single flake of this very hard material lands on a smoothing tool or metal lap, the tool will probably have to be remade or thrown away. Unlike softer abrasives it seems never to break down on glass and will continue to scratch as long as the tool is used. Diamond dust on machines and shelves will do wonders in wearing and scratching. Once anything is contaminated with it, it seems impossible to get rid of it. For this reason diamond dust is always kept wet with oil to reduce its tendency to fly about. With proper care it can be used like any other material but carelessness may result in a situation so bad that the easiest thing you can do is to abandon your shop.

To make the lens mentioned above a concave lap of the proper radius is

cut in soft annealed copper. The lap is then mounted on the spindle and, while slowly rotating, a few drops of olive oil containing a few grains of diamond dust (lapidary grade) are applied with a stick. The diamond powder is then rolled into the surface of the lap with a specially made tool consisting of a handle with a forked extension between whose tines is mounted at right angles a barrel-shaped roller about ½" long and 3/16" in diameter turned out of a drill rod. This is drilled axially with a 1/16" hole for its bearing in the implement. It is then polished, hardened as hard as possible, and repolished with crocus paper. The convexity of the barrel-shaped surface of the roller should be slightly greater than that of the lap, so that the barrel will roll on only a small area. The completed roller should turn freely on its axle and have a polished surface.

When the roller is first applied to the rotating lap it can be felt to roll over the gritty diamonds, but as it is worked all over the surface several times the abrasive sinks in and the rolling action becomes smooth. With a lap of the size described this should take only a minute. The amount of pressure to be used on the roller is difficult to specify. It should be great enough to embed the abrasive but not great enough to deform the lap.

Once the lap is charged it should cut for a long time without any attention. Whenever it seems to be dull it can be recharged in the same manner.

The lens to be shaped is fastened to a handle, pressed against the rapidly rotating charged lap, and worked with the customary motions. For this small size the lap speed can be several r.p.m. The lap must be kept lubricated at all times with oil, preferably olive oil, applied a drop at a time with a stick. It is important that the pressure used on the work be correct, but a feeling for this soon comes naturally. If the pressure is too light the work will skate over the lap with no abrasive action, but if it is too great the abrasive particles will be dug out of the lap and it will need to be recharged.

The lenses that were shaped by the above processes were semi-polished but remained covered with fine scratches from the unsorted diamond material used. These scratches were removed with fine emery on a brass lap. Polishing was then done in the usual manner. If finer grades of diamond had been available, fine grinding and polishing could have been accomplished using additional identically curved laps. It is not feasible to change grit on the same lap, as is done with Carbo, because with this type of charged lap the abrasive remains embedded in the metal.

Rouge: It is generally conceded that no substance puts a better polish on glass than plain red iron oxide rouge. There is, however, considerable variety in the quality of rouges, also several means for refining it when the need arises. Some workers remove the larger particles with a bruiser, working a thin red paste between two glass plates and forcing the big grains to the edge

where they are broken down and lost. Others levigate rouge with dispersing agents and flocculate the suspended material as was described by Parsons in the wartime Roof Prism Program letters. Almost everyone who does careful work washes rouge in some way, even if only to stir it up with water and pour off for use the part that doesn't settle in a given length of time.

Rouge may be used to polish almost any material except metals, many of which are stained by it.

Cerium Oxide: Long in use in France, this material came into widespread popularity during the late war. Pale pink and much cleaner to handle than rouge, it does not "stain" glass and it polishes much faster—some say two to three time faster. In 1947 cerium oxide cost $2.75 a pound in small quantities, which makes it a good deal more expensive than rouge, but the quantity an amateur would use makes the difference inconsequential. Some mirror-making kits now contain this new abrasive and it is preferred by many hand workers because of its greater speed, though they may go back to rouge for figuring because the latter is easier to control.

Barnesite: During the war this mixture of rare earth oxides was used by many large plants. It contains a large percentage of cerium oxide and has many of the same properties. Most samples are dark brown and have a peculiar soft feel. It is claimed that Barnesite polishes almost as fast as cerium and produces as good a surface as rouge. Further, it absorbs water, does not dry out rapidly, and needs less attention on the machine. At present the cost is less than that of cerium.

Putty Powder: This is the lapidary's name for tin oxide, the white, powdery material that Newton used for polishing his metal mirrors. It is also used for polishing petrified wood and agate specimens and is still the best polishing agent for many metals—Stellite, for example, being polished on a beeswax-coated pitch lap with tin oxide. Due to the shortage of tin, putty powder has been hard to get for some time.

Titanium Oxide: So far as I know, no one else uses this substance, which is generally classed as a paint pigment. The duPont grade Ti-Pure R-200 (available only in 50-pound bags) is pure white, easily dispersed, and extremely fine. It does not stain most metals, will polish glass, quartz, and harder gems, and has no peer for polishing plastics.

Finally: Some metals are very difficult to polish and in desperation such unorthodox stuff as lampblack has been successfully used. If you have a grinding or polishing problem you may be forced to discover something new. This list makes no attempt to include even all the commercially available possibilities.

End of article by Holeman. A note on Barnesite, crowded out by the happy report on the 200", will appear later.

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ON THE COVER: The Vickers Hardness Tester determines the hardness of an austempered steel stub in a study of isothermal transformation. For the importance of such studies to modern steel technology see story beginning on page 149.

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Scientific American

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50 Years Ago in . . .

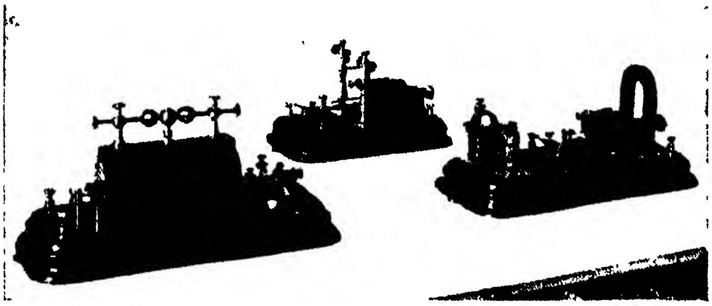
SCIENTIFIC AMERICAN

(Condensed from Issues of April, 1898)

FIRST RAILROAD TO THE ARCTIC SEA — The first railroad running to a port on the Arctic Sea is the continuation of the Vologda Railway, in Russia, which is now finished to the port of Archangel, on the southeastern corner of the White Sea and at the mouth of the river Dvina. This new line, which was opened some weeks ago, says The Engineering and Mining Journal, is nearly 400 miles in length. The Vologda-Archangel Railway passes for the most part through deserted or sparsely populated regions, or across "tundras" and marshes, which are sometimes 50 feet in depth.

AMERICAN SUPREMACY IN THE IRON TRADE — During the past decade there has been a gradual increase in the exports of iron and steel from the United States; but the increase for the past year is very remarkable. From 1866 to 1896, the exports of pig iron rose from 6,659 tons to 29,862 tons. During the same period our exports of iron and steel railroad bars rose from 3,969 tons to 27,645 tons. During the year ending June 30, 1897, however, the export of pig iron was 168,890 tons and the export of iron and steel railroad bars was 112,172 tons. The aggregate value of all our exports of iron and steel to Europe during nine months of the year 1897 was $45,693,000, as against $34,549,000 during the corresponding period of 1896– an increase of 33 per cent. During the same months there was a decrease in the imports from $16,361,000 to $10,032,000.

THE SUBMARINE TORPEDO BOAT — Rightly or wrongly, the naval world believes that the production of a successful submarine torpedo boat will mark the greatest revolution that has ever occurred in naval warfare. The change from sails to steam, the introduction of armor plate, the breech-loading gun, the advent of the torpedo and the torpedo boat, have all in their turn produced radical changes in the construction and the tactics of war vessels, but not any one of them has ever produced the upheaval of long-established customs or the distrust of accepted theories which will occur on the day that a thoroughly practical submarine boat makes its appearance. There is a general belief that an effective under-water warship would have the above-water ship at its mercy, and we think the belief is well founded



WIRELESS TELEGRAPHY — At the present moment, when such strained relations exist between Spain and the country, nothing could be more welcome than the announcement of a practical method of carrying on electrical communication between distant points on land, and between ships at sea During last year Guglielmo Marconi, an Italian student, devoted considerable time to the development of a system of wireless telegraphy, and although he has made use of well known principles, he has so arranged and designed his instruments that he has found it possible to transmit intelligible Morse signals to a distance of over ten miles. It has been left, however, for the American inventor to design apparatus suitable to the requirements of wireless telegraphy in this country. After months of experimenting Mr. W. J. Clarke, of the United States Electrical Supply Company, of this city, has designed, and his company is placing upon the market, such a complete set of wireless telegraphy apparatus that it will in all probability come rapidly into use.

100 Years Ago in . . .

SCIENTIFIC AMERICAN

(Condensed from Issues of April, 1848)

FACTORY LABOR — The Senate and House of Representatives of Pennsylvania have passed the following law:—"Be it enacted that labor performed during a period of ten hours in any secular day, in all cotton, woolen, silk, paper, bagging, and flax factories, shall be considered a legal day's work, and that thereafter no minor or adult engaged in any such factories shall be holden or required to work more than ten hours in any secular day, or sixty hours in any secular week, and that after the fourth of July, of the present year, no minor shall be admitted as a worker, under the age of twelve years in any cotton, woolen, silk or flax factory, within this Commonwealth; that if any owner or employer in any such factories aforesaid, shall employ any such minor, he shall be adjudged to pay a penalty of fifty dollars, one-half to the party so employed, and the other half to the Commonwealth, to be recovered in like manner as debts of like amount are now recovered by law.

CONCRETE — This is the name of a mass of sand and small stones cemented together by lime, or some other cement It would be well if the foundations of all buildings, when there is not solid rock, rested upon a strata of cement concrete Seventy parts of fine stones, twenty parts of sharp river sand and ten parts of good lime mixed with water and grouted in. A good plan is to mix the lime dry with the other material and then throw water over them to make a perfect mixture by turning over There is about one-fifth contraction of the concrete, in reference to the bulk of its ingredients before misture. This would be a fine substrata for plank roads as well as block pavement.

CONSUMPTION AND VENTILATION — Sir Jacob Starks physician to the Queen of England, enumerates as the exciting cause of consumption, "long confinement in close ill-ventilated rooms, whether nurseries, or school-rooms, or manufactories," he also says, "if an infant, born in perfect health, and of the healthiest parents, be kept in close rooms, in which free ventilation and cleanliness are neglected, a few months will often suffice to induce tubercelous chachexia"—the beginning of consumption.—Persons engaged in confined close rooms, or workshops are the chief sufferers from consumption.

NEW BALLOON SHIP — Mr. M. Von Ruyter, a Dutch engineer, has invented a new Aeronautic Ship which rises into the air from the impetus of its own working, with a weight of 200,000 pounds, with immense rapidity, and can be steered at will. Mr. Von Ruyter resides in Rotterdam, and exhibited a short time ago a working model 1 ell 27 inches in breadth and 83 ells 14 inches in length.

AN ANNOUNCEMENT TO OUR READERS

This page in the last four issues of this magazine has been devoted to the description of a new magazine of the sciences which is to be published under the century-old name of the SCIENTIFIC AMERICAN. Next month, May, will see the publication of the first issue of this new SCIENTIFIC AMERICAN.

In August 1845, when the first issue of the SCIENTIFIC AMERICAN was published, the meaning of science was the application of horse sense and mechanical ingenuity to improve the convenience of man's daily life. Nearly all of science was common knowledge. Under its great Editor, Orson Desaix Munn, the SCIENTIFIC AMERICAN became a fixture on the parlor table.

Now, a century later, our entire existence depends upon a science which is no longer common knowledge. The total of scientific information today exceeds the knowledge of any one man. It is the multiplied knowledge of science specialists in hundreds of separate fields.

During the past 50 years science has moved forward at a continually accelerating rate of progress; each new discovery has opened the way for many more. Whole new industries have now arisen at frontiers which were yesterday occupied by the advance forces of research science. Science has become a prime mover of modern history.

Demand For Scientific Information

This new role of science in human affairs has been recognized by a growing community of U. S. citizens. The members of this community have expressed an increasing demand for a source of authoritative and understandable information about science. Though they include experts in each field of science, they recognize that they are all, experts included, laymen before the sum total of scientific knowledge. They want to see science as a whole. They want to follow the major month-by-month advances of science no matter what field they occur in. They want to understand the new advances in the context of the history, the philosophy and the method of science which gives each discovery its meaning.

Their demand for scientific information is overlooked by the two kinds of magazine published today in the name of science. One is the technical journal in which the specialist reports his work to other specialists in the same field. The other is the "popular" magazine of science, published for mass audiences. To fill the gap between these extremes is the assignment of the new SCIENTIFIC AMERICAN.

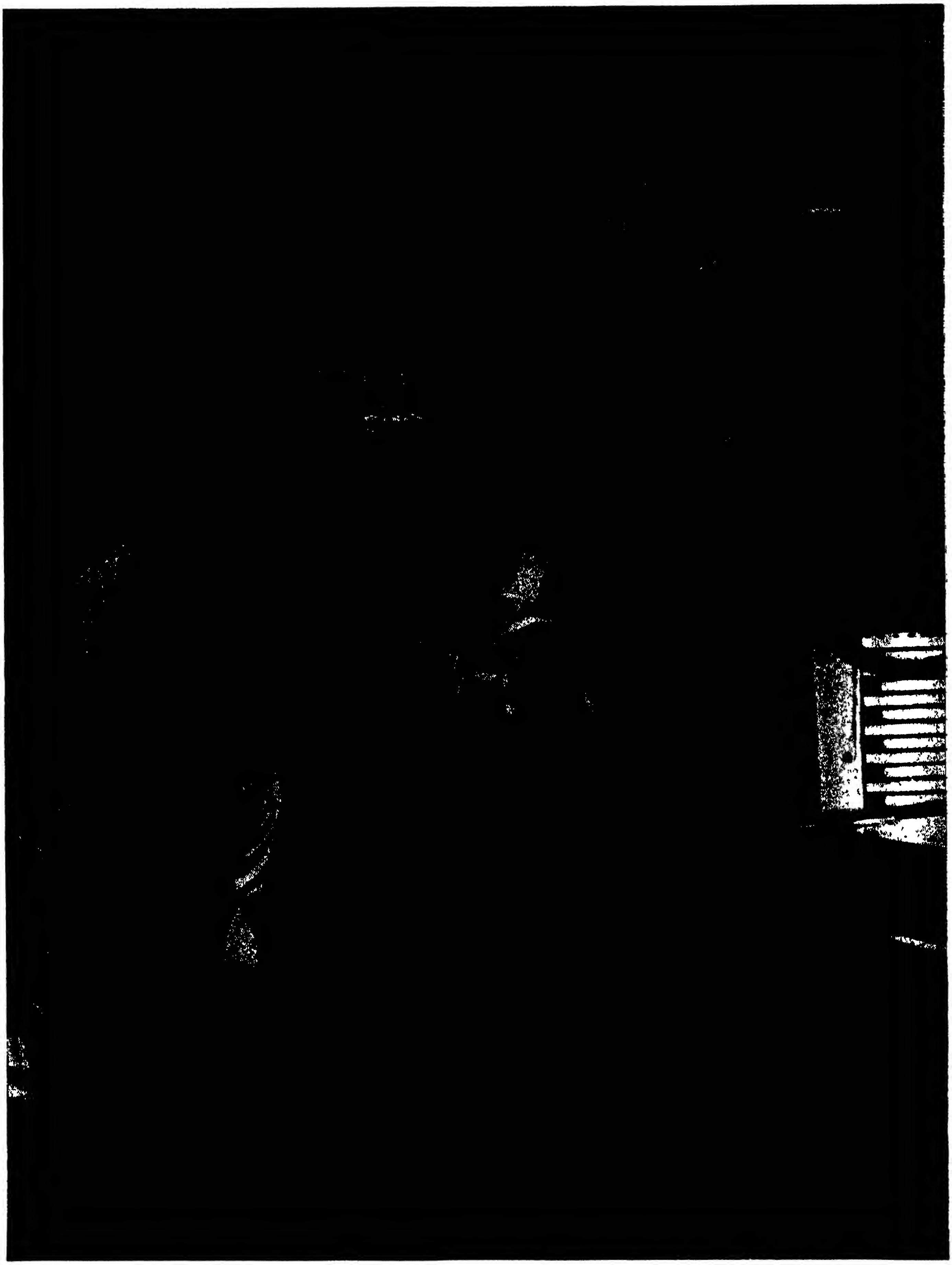
The SCIENTIFIC AMERICAN, its name, goodwill and circulation have been purchased by a new publishing company. Under a new Board of Editors the SCIENTIFIC AMERICAN has become the vehicle for the creation of an entirely new magazine of the sciences.

Scientist and Journalist

The Board of Editors will collaborate directly with the men whose work they report in the production of every article that appears in the new SCIENTIFIC AMERICAN. Many articles will be written by scientists themselves. Others will be written by the Editors and the small fraternity of journalists who are qualified to write about science. In either case, all articles will represent the joint effort of the best talents of scientist and journalist working in close collaboration.

The articles in the new SCIENTIFIC AMERICAN will be written in plain English. Where words are inadequate, the new SCIENTIFIC AMERICAN will make use of the full range of the graphic arts for their power to convey the nature of the tools, the matter and the method of science.

The new SCIENTIFIC AMERICAN will find a unique place among U. S. magazines. It will serve as a universal medium for communication among men in the sciences, and between them and the public that is best equipped to understand their work and purpose It will provide a much-needed "digest" of the technical press. More than a digest, it will organize and relate the basic documents on each subject, which are scattered among the many journals that make up the archives of science. Providing it achieves in performance the high editorial standards on which it has been designed, the new SCIENTIFIC AMERICAN will establish itself as indispensable to the community of U.S. citizens whose demand for scientific information has inspired its creation.



The operator prepares to remove a sample of steel from the heat-treating furnace in a study of isothermal transformations

Scientific American
APRIL • 1948

PROGRESS IN THE HEAT TREATMENT OF STEEL

"Isothermal Transformation" Studies in the Laboratory Have Supplied the Metallurgist With a New Range of Useful Properties

By E. S. Davenport
United States Steel Corporation

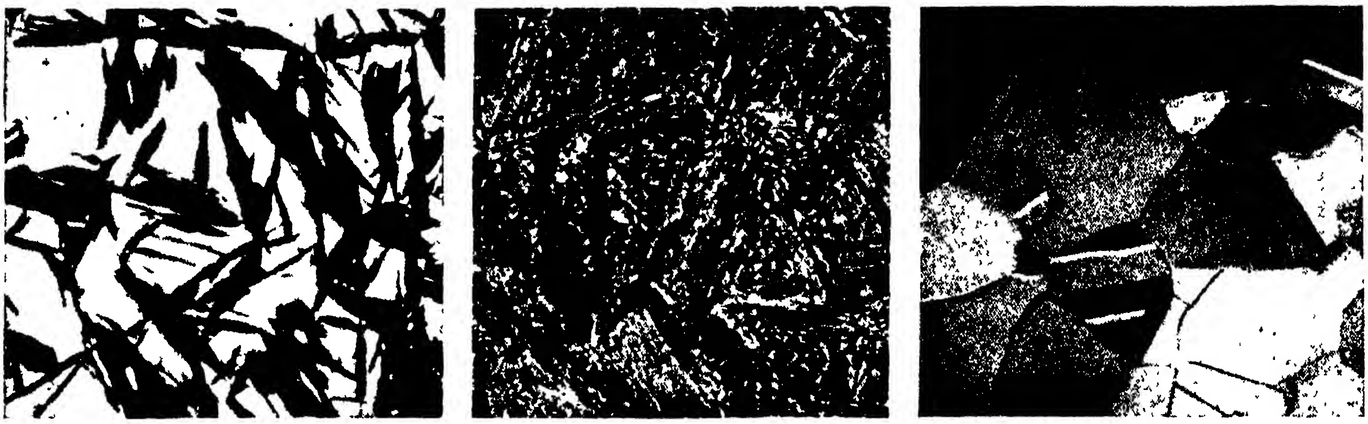
SINCE the days of Tubal Cain, or whoever it was who first fashioned metals for use by man, blacksmiths, armorers and sword makers traditionally practiced the art of hardening iron products on the basis of "handed-down" experience and rule-of-thumb methods, with little or no real understanding of what took place within the metal during the hardening process. In fact, it is only within the last 40 or 50 years, particularly since the development and application of such modern research tools and techniques as the metallurgical microscope, X-ray diffraction apparatus, precise mechanical testing equipment and, more recently, the electron microscope, that metal technologists have begun to get a real insight into the nature of our metallic materials of construction and an understanding of the processes which we employ to control and enhance the useful properties of these materials.

Over the centuries, the hardening of iron and iron-carbon alloys (steel) consisted essentially of heating the metal to a high temperature and then quenching it in some liquid medium such as water, brine, oil or one of the numerous weird mixtures concocted by the early practitioners of the heat treating art. One ancient prescription for hardening sword blades called for plunging the red hot blade into the body of a slave. Quenching was effected *by passing the blade through the thigh of the slave*. The method indicated was too wasteful of slaves, and the ancients—like ourselves—would have hesitated to use it.

What took place within the steel during the quenching operation—that is, what made the steel harden and the actual mechanism of the hardening action—excited relatively little curiosity until about the beginning of the present century when certain French, English and American scientists began to apply the microscope to the study of the internal structure of metals. Professor Henry M. Howe of Columbia University and the Belgian-American Professor, Albert Sauveur of Harvard University, were notable among the pioneer metallurgists in America who devoted much of their effort to the scientific study of steel and other ferrous materials and who helped to train the first generation of metallurgists in this country.

The science and technology of the making, processing and heat treating of steel developed rapidly over the early years of the present century and, as has frequently happened in other fields, the experimenters began to move beyond the limits of the university laboratories and into the industrial research laboratories then just beginning to assume the important role they now play in the economic life of the nation. In the late 1920's the scientists at the newly organized Research Laboratory of the United States Steel Corporation at Kearny, New Jersey, began studies on the fundamental nature of the hardening of steel, using laboratory methods relatively new to metallurgical science. It should be said, however, that these methods had been applied to problems in other fields of physical chemistry long before.

As an example, physical chemists had long been familiar with the abnormal behavior of liquid solutions when cooled under certain conditions. The solubility of a given substance (for example, common salt) in a liquid such as water, is a fixed value at any definite temperature. That is, a definite quantity of water will dissolve only a certain amount of salt at any definite temperature. At a higher temperature, more salt can be dissolved; at a lower temperature,



The photomicrographs show Bainite magnified 2,500 diameters (left) after 50 per cent transformation and (center) after 100 per cent transformation. The structure of Austenite magnified 500 diameters is shown at right

less. When the solution contains all of the salt it is possible to contain, it is said to be saturated By carefully controlling conditions, it is possible to cool a saturated solution in such a manner that it will contain the same amount of salt that it did at some higher temperature. Such an "undercooled" solution is said to be "supersaturated" since it contains more salt than it could under normal conditions. Methods had been worked out for studying the break-down of these so-called "supersaturated" or "undercooled" solutions by measuring changes in chemical, electrical and other properties as the break-down proceeded.

APPLIED TO STEEL — It was a logical step to apply these scientific principles to the study of similar changes or transformations in a solid metallic substance such as steel. However, the experiments with solid, hot steel had to be carried out with the aid of furnaces, microscopes and other metallurgical testing equipment instead of in beakers and test tubes, and many of the experimental steps and observations had to be made at high temperatures in contrast to the room temperature methods and techniques of traditional laboratory chemistry. Although it is not generally realized, modern physical metallurgy is really a special field in the broader science of physical chemistry. While many of the metallurgist's problems involve transformations and reactions in solid as well as liquid metal, the established laws of physics and chemistry apply to his problems with equal force. This holds true even though his experimental technique and equipment may be quite different from the physicist's or chemist's.

This fundamental work on the hardening of steel has been carried on continuously at the United States Steel Research Laboratory for almost 19 years and it has also been taken up and extended by countless other metallurgical investigators all over the world. It is now generally conceded that this new approach to the ancient art of hardening steel has resulted in an entirely new concept of the subject and has cleared the way for many outstanding developments in the treatment and use of modern steels. For example, thousands of tons of special ordnance parts with superior properties were produced in World War II by heat-treating methods based on these fundamental metallurgical studies. Production schedules were speeded up by shortened heat-treating methods made possible by the improved understanding of transformations in steel. In fact, a sizeable industry has grown up around the equipment and industrial techniques which have developed from this research.

The new laboratory technique which the United States Steel scientists applied to the study of hardening permitted the investigators, in effect, to watch the structural changes that took place in the steel while it was undergoing the internal, atomic re-arrangements which occur during the hardening process. This is accomplished by making certain observations and measurements on series of small steel specimens cooled rapidly from a high temperature to some lower temperature. These specimens are then held at this lower, constant temperature while the transformation or change in internal structure goes on More specifically, a series of small steel samples is heated in a furnace to a high temperature, say 1,650 degrees, F., and then rapidly transferred to another furnace filled with molten lead or molten salt at a selected constant lower temperature, such as 800 degrees, F. Each individual steel specimen is held in this 800-degree bath for a different length of time; thus a series of specimens might be held in a series of holding times such as two, four, eight, 16, 32, 64, 128 seconds at 800 degrees.

At the end of each holding time one specimen is withdrawn from the 800-degree bath and cooled rapidly to room temperature in cold water. The treated specimens are then prepared for examination by the metallurgical microscope. If the experimenter has been skillful in choosing the time intervals in the series he will be able to detect in the microstructure, as revealed by the microscope, the beginning, the progress and the end of the hardening transformation as it occurred at 800 degrees, F. Hardness measurements on the same series of specimens give an added check on the microscopic observations. An alternative method of following the progress of the transformation is to measure the changes in length (or volume) which take place in the specimen as the transformation proceeds. This is accomplished by means of an apparatus called a dilatometer which registers, on an indicating dial graduated in ten-thousandths of an inch, the increase in length of a specimen as it undergoes transformation.

A motion picture camera can be arranged to take pictures of the indicating dial at periodic intervals

so the investigator can later project these pictures and read the information he needs to plot the course of the transformation. Still other methods based on changes in density, or in magnetic properties, which take place in the steel during the transformation can be used in such studies. Each method has its advantages and disadvantages and the researcher selects which ever method is best adapted to obtaining the information he needs.

ISOTHERMAL TRANSFORMATION — In this general method of study, known as "isothermal transformation," specimens of many different temperatures below about 1,325 degrees, F., are made to undergo transformation at the same temperature. The results are then assembled in the form of a chart known as the "isothermal transformation diagram" of the steel. Such a diagram shows the elapsed time required for the beginning and end of the change in internal structure, or transformation, at any temperature level, together with other pertinent information of value to the metallurgist and heat treater.

As an illustration, let us assume that the investigator has carried out his isothermal studies at 100 degrees, F., intervals from 1,300 down to 400 degrees, F. He has ten sets of observations, one at each of ten temperature levels. He then prepares a chart showing where transformation begins and ends at each level. He may also plot points for intermediate amounts of transformation. Now if he connects the points representing the beginning of transformation at all ten temperature levels he will have a curve which shows how the time for beginning of transformation varies with temperature. Likewise, if he connects all the points for the ending of transformation he gets a curve showing how the ending time varies with temperature. This type of information has proved to be of great value to heat treaters by showing them how fast they must cool the steel through certain regions of temperature in order to successfully harden the material in a quenching operation

In addition to the above-mentioned curves, the investigator may indicate on the chart the type of microstructure that formed at each temperature level and the hardness of each structure, together with such other special information as may be of interest to the heat treater or ultimate user of the treated steel. The information on such a chart may also be used as a guide in developing greatly shortened heat treatments to *soften* steel, in contrast to *hardening* it. Such softening or so-called "annealing" treatments are often required to put the material in proper condition for machining or forming operations. These annealing treatments may often by long, drawn out affairs requiring many hours or even days to complete by older methods. Information summarized in the isothermal transformation diagram thus shows metallurgists how to save many valuable hours of furnace time.

Isothermal transformation studies reveal many startling facts about the hardening of steel—facts which were entirely unknown or only vaguely suspected until this work was undertaken. It was discovered, for example, that at certain temperature levels

Structures of the transformed metals are examined under a metallographic microscope

The high-speed photograph shows a sample bar of red hot steel being plunged into a bath of still oil as part of the quenching operation in the study of isothermal transformations

the transformation may complete itself in a matter of a few seconds or even fractions of seconds, while at other temperature levels the time required may run into hours, days, weeks or even months depending upon the chemical composition of the steel and other factors under the control of the steel maker and heat treater. Moreover, it soon became evident as the investigations progressed that each type of steel composition had a characteristic isothermal transformation diagram of its own and that many of the virtues of the alloy steels were traceable to their fundamental transformation behavior. Gradually, as more and more diagrams were worked out for different steel compositions, the specific effect of each of the common alloying elements (e.g., chromium, nickel, molybdenum) became clear. This enabled the metallurgist to predict what might be expected of new or proposed compositions. As the study of the more complex steels, containing several alloying elements, was taken up, a great deal of valuable information was accumulated on these important materials. Much of this was immediately applicable to a wide variety of products.

It should be emphasized that all of this work involved a great deal of effort by a large group of investigators over a period of many years. For example, to work out the isothermal transformation diagram of even a single steel composition may require the preparation, treatment and examination of well over a hundred laboratory specimens. In the case of alloy steels of more complex composition the time involved in the transformation often becomes longer, the microstructure becomes more difficult to interpret and the investigator is forced to feel his way, setting up new standards of comparison as he goes along, backtracking, discarding, revising his ideas and interpretations and making new hypotheses about matters that fall outside the realm of previous experience. Such a long-range research program requires time, patience, faith and continued financial support.

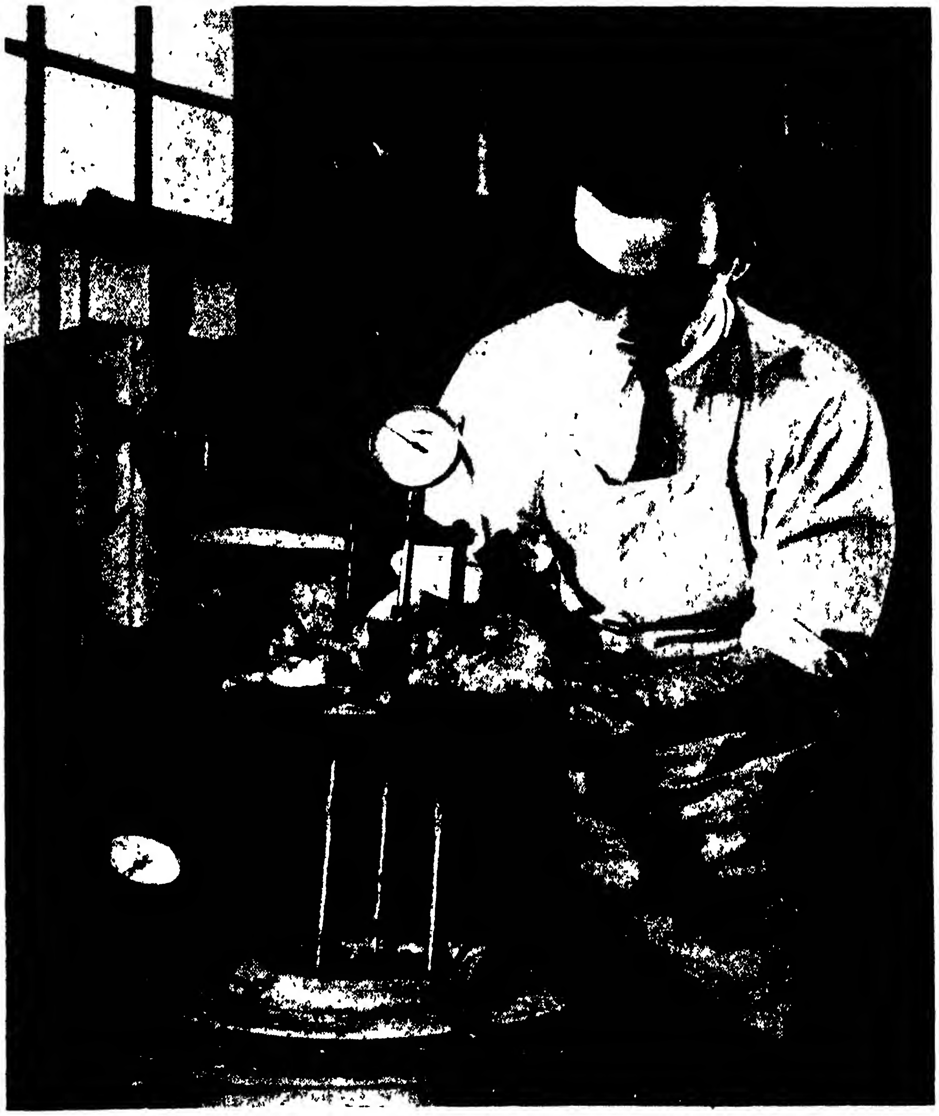
By the end of 1943 United States Steel's investigators had been working on this problem steadily for over 14 years and had accumulated a sizeable body of information on the subject. Some of this had been made available to other research workers in the form of papers and articles presented before scientific and engineering societies or published in technical journals. It was then decided to make this information more widely accessible to industry in general. Late in 1943 the Corporation published a 104-page booklet entitled "An Atlas of Isothermal Transformation Diagrams" containing 56 of these diagrams and covering a total of 47 different steel compositions.

NEW HEAT TREAT METHOD — One of the unpredictable by-products of these researches on the fundamentals of heat treatment was the discovery and development of an essentially new method of heat-treating steel, which came about as follows. In the early days of the work at the United States Steel Research Laboratory it was observed that a hitherto unknown microscopic structure formed in the steel if it was caused to undergo transformation at constant temperature within a certain temperature range, usually between about 450 and 950 degrees, F. Since this structure, now called "Bainite" after one of the original observers, was entirely new to the investigators, it was decided to look into the mechanical properties of steel having this particular microscopic structure. It was revealed that many types of steel treated in

this way exhibited a remarkable degree of toughness or ductility at relatively high hardness. The same steels treated by the older, customary methods were always lacking in toughness at high hardness. This led to further investigations culminating in the commercial development of an entirely new method of isothermal heat treatment which came to be known as "Austempering." This method was successfully used in many wartime products and is undergoing further commercial development. Variations of this isothermal treatment were explored by many other investigators and metallurgists, with the result that today several well-recognized methods exist for heat treating steel by isothermal means, all having their roots in the information presented in isothermal transformation diagrams.

In its broader aspects, this work of United States Steel's scientists, which began as a scientific investigation of the transformation process in the interest of a better understanding of metallurgical changes, has grown to have widespread industrial implications in the field of practical heat treatment. It has had a pronounced influence on the thinking and practices of metallurgists throughout the world. The following few examples of peacetime steel products, the quality and utility of which have been enhanced as a result of isothermal transformation researches, will give some idea of the scope of this metallurgical development: a wide variety of simple tools such as garden and farming implements, hammers, chisels, axes, screw-drivers, in fact, any tool that should embody a high degree of hardness without sacrifice of toughness; numerous machinery parts such as needle bearing pins, springs, bobbin rings, snap rings, lock-washers, linotype and typewriter parts, kicker and knockout pins, clutch parts, various wire forms requiring high hardness, similar applications of thin steel parts requiring a combination of hardness and toughness; miscellaneous articles such as shoe shanks, safety toe caps, knife blades and knife back springs, miscellaneous hardware, firearm parts, link chains, rolls, sidebars, fishing rods, golf shafts, and many others too numerous to mention. In fact, the whole broad range of steel products which undergo heat treatment, either during processing or as a final operation, have been benefitted by the increased metallurgical knowledge accruing from isothermal transformation studies.

The dilatometer. With this device the operator can measure the progress of the isothermal transformation by measuring the changes in length which take place in the specimen as it is held at a constant temperature



THE WORST WEATHER IN THE WORLD

The Freezing Winds and Perpetual Moisture At the Summit of Mount Washington, Tallest Peak in the Northeastern U. S., Make It an Admirable Proving Ground to Test Equipment Which Must Withstand Less Severe Conditions

By Martin Sheridan

TWENTY five hundred miles south of the Arctic, within sight of the Atlantic Ocean rears a wind-swept mountain blanketed by Arctic tundra, cold-stunted trees and Arctic flowers. It has Arctic weather in abundance—sub-zero temperatures, winds of greater-than-hurricane force, blowing snow, ice and freezing clouds.

The peak is Mount Washington, towering 6,288 feet above sea level in the rugged White Mountains of New Hampshire. It used to be as devoid of human life in the winter as the ice cap in Greenland. Today, however, a score of hardy young men inhabit the summit.

Three men run the Mount Washington Weather Observatory, one of the most important links in the nation's weather forecasting system; three engineers and two cooks man the Yankee Network's Frequency Modulation transmitter next door; a dozen Navy, Army and private researchers are stationed there to collect data on icing conditions and other vagaries of the weather.

At the end of the long flight of stairs are the quarters of the Navy engineers stationed atop Mount Washington

NATURAL COLD LABORATORY — During more than half the time from October to June Mount Washington, the tallest peak in the Northeastern United States, is enveloped in freezing clouds which deposit tons of ice on its summit. From the research standpoint, therefore, Mount Washington is of enormous value as a "cold laboratory" to aviation and to de-icer and Arctic clothing manufacturers. In addition, power companies, railroads, communication and transportation companies, and resort areas are aided immeasurably by the reports from the tiny weather station.

Late last September the Navy hauled a jet fighter plane up the tortuous eight-mile mountain road to be anchored for the winter in an open-ended wooden hangar so engineers might try to correlate engine and wing icing conditions. Two huge tank trailers loaded with high-octane gasoline also made the difficult climb to the summit and were left there to furnish fuel for power runs. The plane, a McDonnell Phantom (FD-1), is faced into the prevailing west wind and anchored into the mountain with steel eye bolts which extend 18 inches into the solid rock. Should the plane be blown away during a storm, a good part of the mountain would be carried away with it.

One of the pertinent questions that the scientists hope to be able to answer as a result of this research is: will the jet engine or the plane's wings ice up first under Arctic conditions? Constructed like a small wind tunnel, the hangar has a canvas drop at either end to protect the research personnel during non-test periods. The building has a steel frame skeleton covered with two layers of rough boards. The interior is lined with cement asbestos board. According to the Volpe Construction Company, builders of the

hangar, the steel frames were anchored on wooden sills which in turn were anchored to the rock with steel dowels.

Unlike a cold wind tunnel Mount Washington's natural testing laboratory furnishes *true* cloud icing conditions which cannot be simulated at any cost. The correct size of the water droplets and their proper distribution in the clouds cannot be reproduced artificially—not even at Eglin Field, Florida, the Army's $10,000,000 cold laboratory.

In charge of the project atop Mount Washington is the Air Co-ordinating Committee of top-ranking Army and Navy officers. This agency has contracted with Smith, Hinchman and Grylls, Inc., an engineering and architectural firm of Detroit, to provide housing and food for the engineers and researchers living on the mountain.

Both the Army's Air Materiel Command and the Navy's Aeronautical Engineering Laboratory direct the engineering research, while Harvard University is under contract to the Army's Atmospheric Laboratory to conduct studies on the basic physics of icing Wallace Howell, research fellow at Blue Hill Observatory, is field director of the Harvard program

The late Salvatore Pagliuca, former director of the Yankee Network's Weather Service and one of the original three modern weather observers to spend the first winter at the summit in 1932, conducted the first observations of icing conditions in 1934. He used wing models at that time to investigate the size of cloud droplets for the Massachusetts Institute of Technology. Since 1941 a device called a multicylinder which is composed of several small cylinders of varying diameters on a long metal rod has been used to measure the liquid water content of clouds and the distribution of the size of the droplets During the war, weathermen measured ice formations every three hours. They were assisted for a time by the Army's 8th Weather Squadron.

This model of a DC-6's nose mounted on the cog railway trestle aids in the study of ice formation on aircraft

WARTIME RESEARCH — Other wartime research on Mount Washington covered:

Studies for the B. F. Goodrich Rubber Company of an aircraft wing de-icer. This rubber de-icer was installed on the forward section of a plane wing which was mounted on the water storage tank. Extensive observations of the tensile strength and adhesiveness of the ice, were made.

Development by the General Electric Company of the multi-cylinder and other instruments for measuring the atmosphere.

Work on a cloud meter to measure the water content of clouds.

Installation of an Army automatic weather station for tests by a weather squadron that pitched tents and lived below the summit for several weeks.

Testing of wearing qualities of phosphorescent paint for the U. S. Navy.

Testing of Goodyear synthetic rubber tires mounted on an automobile that was driven up and drown the mountain early in the cold season. An unexpected crippling snow storm in October trapped the vehicle on the mountain for the next eight months.

During the winter of 1946-47, Northwest Airlines, then under contract to the Army Air Forces, mounted a 2,200-horsepower Pratt and Whitney aircraft engine on a tank-like vehicle in the same location where the jet plane is now anchored. Engine controls, switches and gages were located inside an enclosed cab, thereby enabling parka-clad hermits to run the engine and conduct their experiments. The results have not yet been announced

Mount Washington has always been the most lonely, windy, foggy, storm-racked and generally God-forsaken spot in America in which to spend the winter. But the introduction of a few innovations has made the lot of the weather observatory crew, the FM radio station operators and the government-sponsored researchers a bit less arduous. An electric window has been installed in the main observatory room to enable the men to make observations without going outdoors. Constructed of NESA glass with a special metallic coating, the window is heated with four amperes at 115 volts to prevent the formation of fog and ice. Instead of the old electrically-heated anemometer, pitot tubes (similar to those used in planes to record air speed) automatically record the wind velocity. An efficient oil-burner, replacing the old coal furnace, has been installed for heating the observatory building. The weather observers have electric foot warmers and electric blankets. Also, there is a sun lamp to supply vital health elements.

TWENTY-DAY SHIFT — All the inhabitants of the mountain work on a 20-day shift, with 10 days off. They must be rugged enough to brave frigid blasts encountered during their trek down the mountain for a respite in the valley or a visit to Boston—170 miles distant. The recent war has made even that task easier with the introduction of an Army weasel (tractor vehicle) at the Glen House in the valley for transporting the men part of the way up the mountain road. Compare these comforts and conveniences with the hardships suffered by the Hitch-

cock-Huntington Expedition of six men who occupied Mount Washington for six months during the winter of 1870-71 as the peak's first weather observers. Of that first winter, J. H. Huntington wrote in his log:

"The wind roared terribly, as if inspired with the power and spite of all the furies, and the wild rage was so deafening that we were obliged to shout to our utmost to make ourselves heard. . . In the room at no time has the temperature been higher than 35 degrees. And to accomplish this we have the stoves at red heat. The thermometer hangs precisely five feet from the stove. Ten feet from the stove at the floor the temperature is 12 degrees."

One of the pioneers froze to death.

Two members of the United States Signal Service, forerunner of the present Weather Bureau, were assigned to the summit from 1871 to 1887 and for the following five summers. No one dared to brave the winters on Mount Washington again until 1932, when Alexander McKenzie, Robert S. Monahan and Salvatore Pagliuca volunteered to serve without pay and report by radio to Albert Sise, an enthusiastic radio ham in Boston.

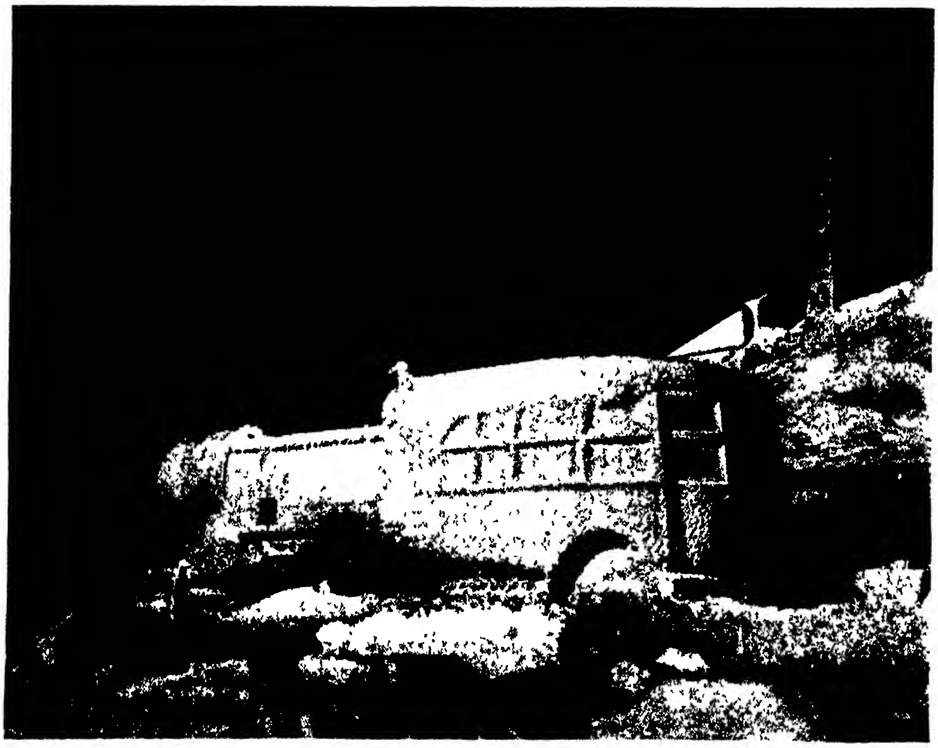
That winter found the slopes of the White Mountain region dotted with ever-increasing numbers of men and women on skis. A few summer hotels remained open all year 'round for winter sports enthusiasts and prospered Mount Washington weather reports became the focal point for ski information. On the tiny observatory's promise of snow, the Boston and Maine Railroad advertised its first ski train leaving Boston on February 12, 1933. That Saturday afternoon four inches of snow fell, assuring the 1,000 persons, who arrived at Crawford Notch in 34 passenger coaches hauled by five locomotives, of excellent skiing conditions.

The present observatory was completed in 1937 with funds contributed by the Mount Washington Cog Railway, the Mount Washington Observatory and the Yankee Network. The building is constructed on 9 by 10-inch railroad ties securely mortised, the foundation fastened to 10 four-foot long bolts extending into solid rocks or blocks of concrete. The roof of the two-story building is trussed, braced and chained beyond description. No other building—wood or brick—has withstood the total annual wind velocities of more than 320,000 miles recorded at Misery Hill!

Imagine a place blanketed in heavy fog 53 per cent of the year; where more than 25 clear days out of 365 would be a record; where a temperature of 46 below zero has been recorded. Flurries not included, snow has fallen on the summit during every month since September 1939. Summer temperatures have dropped to 22 degrees, F., and the all-time maximum is 73 degrees. In 1934 a special anemometer registered a gust of wind with a velocity of 231 miles an hour—the highest ever officially recorded anywhere. The average rainfall is 80 inches, the average snowfall 208 inches.

Scientists describe the weather atop Mount Washington as the worst in the world. It is certanly the worst weather in which man is living. The continuous sub-freezing temperatures, super-hurricane winds, blowing snow and absence of sunshine support this belief. Though temperatures do not average as low as those in the Arctic, high winds and low temperatures nearly always attack together on Mount Washington and thus the chilling effect is tremendous. The severity of the cold is increased beyond conditions in the Arctic where low temperatures seldom are accompanied by high winds.

Mount Washington in winter is a mountain of misery. But the hardy young men who brave it risk madness from sheer monotony and the world's worst climatic conditions in the interest of science.



The 2,000-horsepower Pratt and Whitney aircraft engine was mounted on this vehicle with all controls and instruments located in the enclosed cab so that the engine could be thoroughly tested under the most severe weather conditions

PHOSPHORUS: BEARER OF LIGHT AND LIFE

The World Shortage of Food Is Partly the Result of a Shortage of Phosphate Fertilizer. The Second of Two Articles

By William Mann

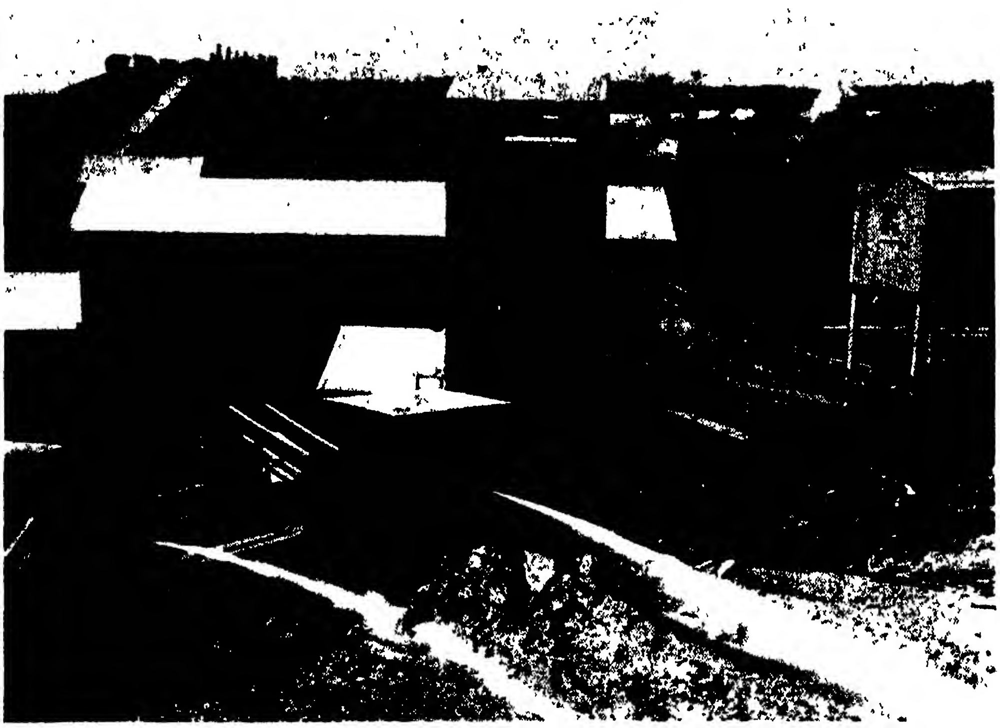
"THE BEST soil manure of all is human blood," says the author of *Kitab al-Falahah*, a medieval treatise on agriculture. One wonders how this Tenth-Century Arabic author discovered such a gruesome fact, if it is a fact. Human blood is a nitrogenous material, but nowadays it is not applied to the soil for nutrient purposes, although this may well have been done in the more ruthless youth of mankind. In our own time there are more efficient ways to bring in a crop, but even now maintenance of the food supply is one of the greatest causes of concern and cruelty. There are few things more apt to whip simple men into a desire for war than exaggerated fear of danger to the food supply. War guarantees that the food supply will get badly out of joint in the lands where the fighting takes place.

It is significant that all of the five official reports on which the European Recovery Program is based emphasize the prime need of that continent for fertilizers before hunger can be abated and recovery can begin. The need of hard-worked soils for nitrogen, phosphorus and potassium is acute. Despite the great loss of life during the war, the population of every nation in Europe except France has increased since 1939. These additional hungry mouths make it essential that soil nutrients be replenished. Many of the farms of Europe have undergone accumulated starvation for fertilizers ever since the fall of France.

Mining matrix—phosphorus-bearing rock

PHOSPHATE AND FOOD — An intelligent visitor from Mars, suddenly presented with a copy of the Harriman Report on the basis of the Marshall Plan, would probably consider the present difficulties of Europe incomprehensible, especially the superphosphate deficiency. Lying in North Africa are some of the largest and best phosphate deposits in the world. One would suppose that such an excellent source of soil nutrients would be gratefully accepted and intensively used by a crowded region constantly suffering from population pressure. But, as the Martian will learn from the Report, in 1940 the inhabitants of Europe abruptly stopped applying phosphorus compounds to the soil. Instead, phosphorus was suddenly diverted to fill mortar and howitzer shells for smoke screens and compounded into flame-throwers, all for death-dealing purposes. Our visitor from Mars might cynically conclude from this that Europe was bent on thinning its population to relieve the pressure. Not at all! Even after a large American army was transported to Europe with phosphorus in new and exceptionally malignant forms, we find that the total population of Europe has risen and the need for fertilizers is now greater than ever.

America was fortunate enough to wage a successful commuters war, and therefore the phosphate situation is rather better at home. Since 1940, when the European fertilizer industry began its enforced vacation, 125 new fertilizer plants have been built or are now in course of construction in the United



Matrix brought in from the mine is dumped on a large pile and sprayed with high-pressure streams of water. The resulting slush drains off and is carried away by conduits to be processed

States Not all of these are superphosphate plants of course It is estimated that in the twelve-month period ending on June 30, 1948, our phosphate industry will produce the equivalent of 10,000,000 tons of normal superphosphate. This represents about 1,850,000 tons of phosphoric acid and includes plant nutrient phosphate in all its various forms. Our needs will therefore be adequately met.

But let us leave the social problems of phosphate and return to chemistry, which is a good deal simpler. The use of phosphate compounds as fertilizers is the oldest use of phosphates by man, and it still demands a larger tonnage than any other application. This fact also has an important indirect effect on the chemical industry in general. For instance, when one reads of the enormous basic importance of sulfuric acid to industry, it is well to remember that its greatest use in war or peace comes from the manufacture of superphosphate fertilizers.

COMPLICATED CHEMISTRY OF PHOSPHATES — One of the things that has often worried soil chemists is the fact that most phosphate is wasted, even when the highest concentrations are applied. Only 10 to 30 per cent of the quantity added to a given soil immediately before planting is recovered through the crop. The rest of it is "fixed" in the soil; that is, something happens which renders it permanently unusable by the plants.

What becomes of the unusable 70 to 90 per cent of this rather expensive material? This problem is considered so important at present that the Tennessee Valley Authority recently (in 1947) assembled the nation's leading agricultural chemists at Muscle Shoals for a week-long conference. As a result of these discussions an extensive program of research was recommended, including study of "fixed" phosphate and of the properties of elemental phosphorus, using radioactive tracer techniques. For many years it was assumed without convincing proof that the bulk of the lost phosphate was consumed by micro-organisms in the soil. It is now known that soil organisms, like the useful ones that manufacture the antibiotics, are nearly innocent of making off with any significant amount of phosphate. Apparently, the loss is due mainly to precipitation and adsorption in the soil, rendering the fertilizer insoluble again, as it was before the original rock was treated. Iron and aluminum are the chief precipitating agents in acid soils. The phenomenon remains obscure and still requires study.

As a matter of pure chemistry the interrelation of the numerous phosphate salts has baffled chemists longer than many other compounds, perhaps because they have been more intensively studied by so many investigators Almost exactly a century ago, in 1849, Dr. Heinrich Rose of the famous German family of chemists summed up his years of study of the remarkable phosphate family with these words:

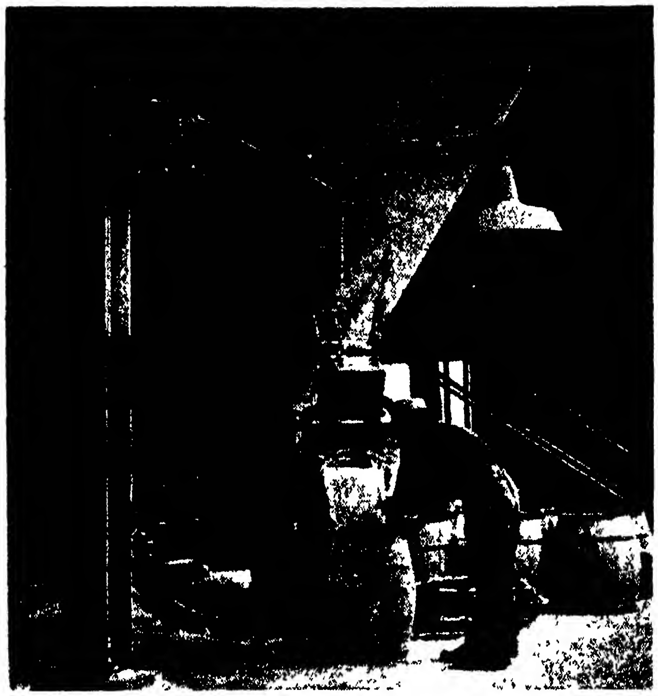
"No substance offers the chemist greater difficulties than phosphoric acid, and the longer the behavior of the acid is studied the more the difficulties increase. Each new investigation presents the chemist with new anomalies; fresh and puzzling phenomena constantly make their appearance while the older well-known difficulties still remain."

Although the learned Dr. Rose did not really know what difficulties remained, and although much progress has been made since 1849, his dictum is still true to a remarkable degree. In recent decades, since phosphate compounds have proved themselves useful in so many new ways, the situation is seen to be even more complex than Rose imagined. An astonishing array of complicated and dubious formulas for phosphate salts of commercial value can be

found in the scientific literature. Conflicting data are described in many instances, and it is clear that not a few people have published material that cannot be confirmed.

It was Dr. Rose who first prepared and analyzed the now famous salt, $Ag_5NaP_6O_{18}$. This compound is important as a type of metaphosphate salt with an alkali metal, sodium, *inside* its molecule. This is something that does not often happen and it leads to very interesting related phenomena. Metaphosphates are of great and increasing importance in the whole range of industry, in the huge fields of water-treating, detergency and food and fibre processing. The mother of them all is metaphosphoric acid, HPO_3, a deceptively simple looking compound which possesses, with its numerous salt offspring, the most complicated properties of all the complicated phosphorus acids. The reason for this is the strong tendency that these molecules have to polymerize, that is, to manifest a certain chemical clannishness which causes them to hang together and form varied products of high molecular weight called polymers. Moreover, on what seems like rather slight provocation, the metaphosphates will also isomerize, which is a species of chemical inter-breeding whereby the same atoms arrange themselves differently within the new molecule; the isomers thus formed are able to present different properties while retaining the same molecular weight. The metaphosphates are inorganic compounds, of course, but in polymerization and isomerization they exhibit the kind of behavior that makes organic chemistry so exasperatingly fascinating. In fact, the behavior of the larger metaphosphates is still so baffling that for the present most chemists do not try to work out definite formulas for them all.

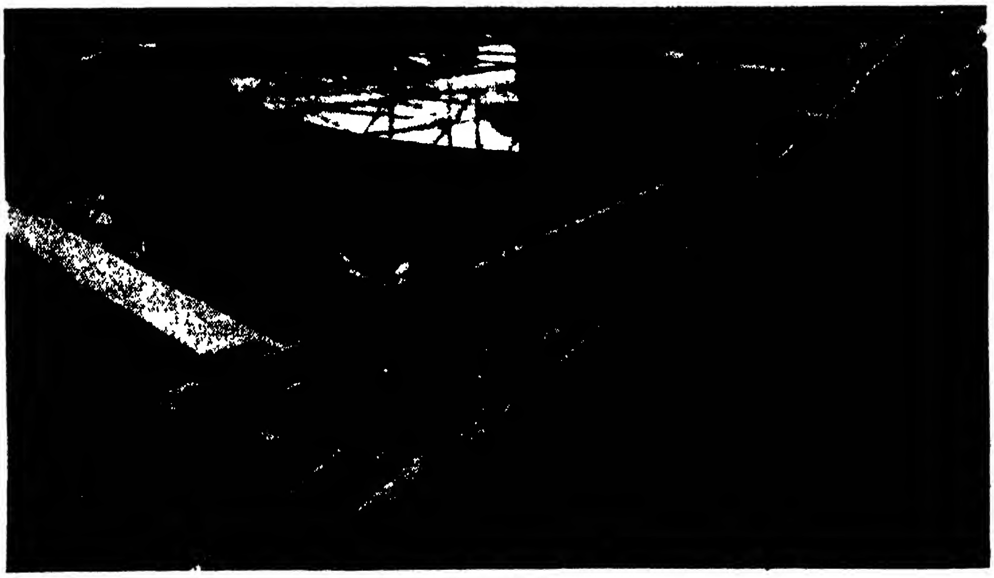
AN EXPANDING INDUSTRY — Yet they are of constantly increasing importance, as we have said. Sodium metaphosphate is widely used under a number of trade names in treating boiler water, in laundry operations, and in the textile industry. The calcium and potassium metaphosphates have also received considerable attention because of their value as fertilizers, their chief advantage being an unusually high plant nutrient content.



A phosphate product being packaged for shipment

It may be well to mention here, since there seems to be a lingering doubt in many people's minds, that the Esch Bill passed by the United States Congress some 35 years ago, effectively did away with phosphorus necrosis in the American match industry. At one time white phosphorus was a serious menace to the health of match workers, but no longer. In fact, a major match manufacturing company sacrificed its patent rights in order to make the Esch Bill work. By this act of commendable altruism, a large corporation made commercially valuable information on the important substitute, phosphorus sesquisulfide, freely available to all of its competitors. The research and development work for this had cost the stockholders a good deal of money. Without the earlier efforts of such bold reformers, match workers might

Here martix is sized and concentrated. In the large circular tanks, called classifiers, impurities are settled out and the material moves over conveyor belts to the sintering plant



still be going about with their teeth falling out and their jawbones dropping off from the horrible effects of "phossy jaw."

The baking powder industry is reported to be the second largest consumer of phosphate rock. It is estimated that over 160,000,000 pounds of baking powder are consumed in the United States per annum. The function of this powder is, of course, to leaven dough. Nowadays, baking powders generally consist of a dry mixture of sodium bicarbonate with one or more acidic compounds capable of completely decomposing the bicarbonate into carbon dioxide gas. This prevents the precipitation of sodium carbonate or washing soda in the bread. The use of acid phosphates for this purpose is constantly increasing. They have an advantage over the older alum and tartrate powders in that the phosphates left behind by the new products are believed to be good for the growth of bone and muscle. The chief phosphates used for baking are the monocalcium and monosodium phosphate salts. Straight phosphate baking powder is a mixture of these two with sodium bicarbonate and diluents and fillers such as cornstarch or flour.

SOME NEW COMPOUNDS — Millions of dollars have been spent by firms on research of the new organic phosphorus compounds. Much of this work is still in course of development, but there can be little doubt that some of it, especially in the fields of plasticizers for the plastic and lacquer industries, inhibitors for rancidity of oils, and specific corrosion inhibitors will prove valuable in the future. The newer food uses include the important medicinal compounds, the glycerophosphates and the hypophosphites as well as phosphates containing sodium and calcium. The latter are considered a good source of two important constituents of men and animals. Sodium ferric pyrophosphate is reputed to be a good means of getting valuable iron into the body.

Water treatment is an important industry in which great quantities of phosphate compounds are used to soften water, decrease its corrosive properties, and help loosen dirt. Trisodium phosphate has long been standard for these purposes, but research has lately introduced many of the fancier hexa-,pyro-, and poly-phosphates, which are reputed to be better. We have already mentioned the organic esters of phosphoric acid. Phosphorus is also important in metallurgy as an alloying agent. It is still absolutely necessary in the match trade, both as an element and in compounds. It is an important catalyst in petroleum refining. The soft drink industry alone buys pure phosphoric acid by the ton for use in its beverages. Altogether, it is no exaggeration to say that all large industries use the phosphorus atom in one form or another. It is essential to many trades—paper making, brewing, cellulose, dye, soap, printing, leather and rubber, to name a few. In fact, the phosphate industry is one of the most progressive in the United States. Although it is no longer young, it seems to be one of the few really capable of challenging developments in the great new organic chemical industries and of giving them a real run for the consumer's dollar.

Workers direct the flow of molten slag and ferrophosphorus from the electric furnace to the cooling ponds

MANUFACTURING ADVANCES IN WARTIME GERMANY

Machines and Processes Which Were Developed in Competition With Allied Engineering Brains Are Now Available to U. S. Industry

By John L. Kent

MANY ALERT American manufacturers can improve their products, add profitable lines, and even start new businesses by making use of technical information on German processes and equipment which can be obtained from the Department of Commerce. The Department's Office of Technical Services is releasing thousands of reports on German science and industry based on investigation by OTS industrial intelligence "detectives."

During the past two years these investigators have surveyed all German advances which could be of value to American industry and their reports can be obtained merely for the cost of reproduction.

Many of these reports, containing descriptions of processes and equipment, formulas, plant layout and other technical data, sell for less than a dollar! American firms and individuals are buying them at a rate of $1,000 worth a day.

COLD STEEL EXTRUSION — Job stamping shops and manufacturing shops which do sheet metal stamping will be interested in a report on a process developed in Germany to extrude cold steel just as we extrude tin, zinc, copper and other non-ferrous metals. German success in making cold steel "flow" under pressure opens up wide possibilities for American manufacturers. OTS investigator, W. W. Galbreath, says the process, which uses special dies and the application of a phosphate bonderizing treatment, can result in remarkably reduced costs for the production of many common steel objects.

The cold extrusion process promotes greatly increased production. For example, in shell fuses, where we produced a unit every two or three minutes, the Germans by the use of the cold extrusion press made approximately 20 or 30 per minute. The extrusion process also enables the manufacturer to make thousands of intricately shaped parts which cannot be made by the stamping procedures now

An experimental cold extrusion press. During the war the Germans succeeded in extruding cold steel with such a machine. The press is said to make possible greatly reduced costs in the production of many common steel objects

employed. Only a small amount of new equipment will have to be obtained because the work is closely associated with that normally done in job stamping shops and the cold extrusion dies are of the same general type as the dies used for stamping.

The process offers an unusual opportunity to American manufacturers for making parts now produced from malleable iron castings, drop forgings, or machined from bar stock. The German process requires little machining, and in some cases no machining at all. It is now being tested by the Heintz Manufacturing Company, Philadelphia, under a contract with the U. S. Army's Ordnance Department.

The bonderizing treatment used in the cold extrusion process is also expected to solve one of the difficulties encountered by small firms engaged in sheet metal drawing. Often poor design of molds and equipment causes tearing or results in unsightly ridges or corrugations in the finished product. The problem is friction. The remedy is a low-friction surface on both sides of the metal sheet so that the metal will flow freely when it is pressed into shape.

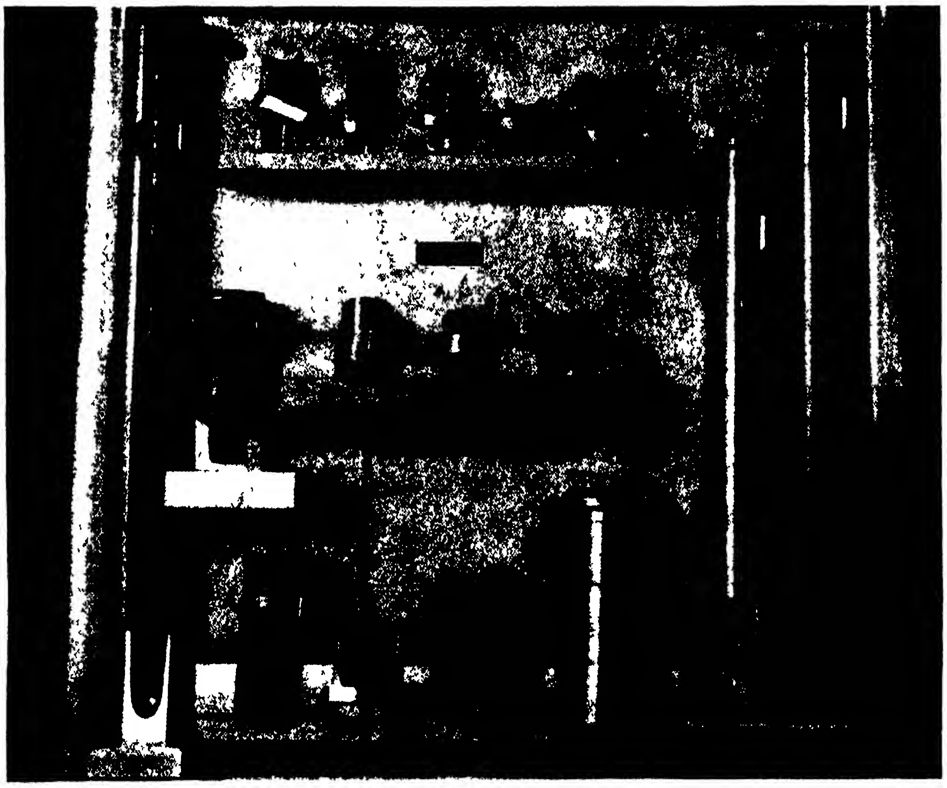
Investigations in Germany reveal that successful use has been made of zinc coatings (or bonderizing) that are applied on both surfaces of sheet steel to reduce the friction and to permit particularly extensive draw.

The procedure has markedly increased production and diminished the need for the establishment of large press facilities in the plant and extensive research upon lubricant media. The zinc coating process does not seem to be too difficult for the small manufacturer to employ. Equipment is not too expensive and the final product is of high quality. The coating processes will also be of interest to other manufacturers who produce cold reduced steel solids such as cold drawn wire and cold drawn rolled thread screws, because it reduces the number of intervening heat treatments and subsequent scale removal processes.

SALT BATH HEAT TREATMENT — Commercial heat treating firms will be interested in German salt bath heat treatment methods by which close control of temperature was obtained without undue attention to instrumentation. The Germans have used salt baths for many years as their chief means of heat treating and during the war extended their knowledge of salt baths for case hardening, decarbonizing, neutral surface treatments and for quenching as a substitute for oils which were in short supply. Information on their practices and research was obtained from several large metallurgical plants.

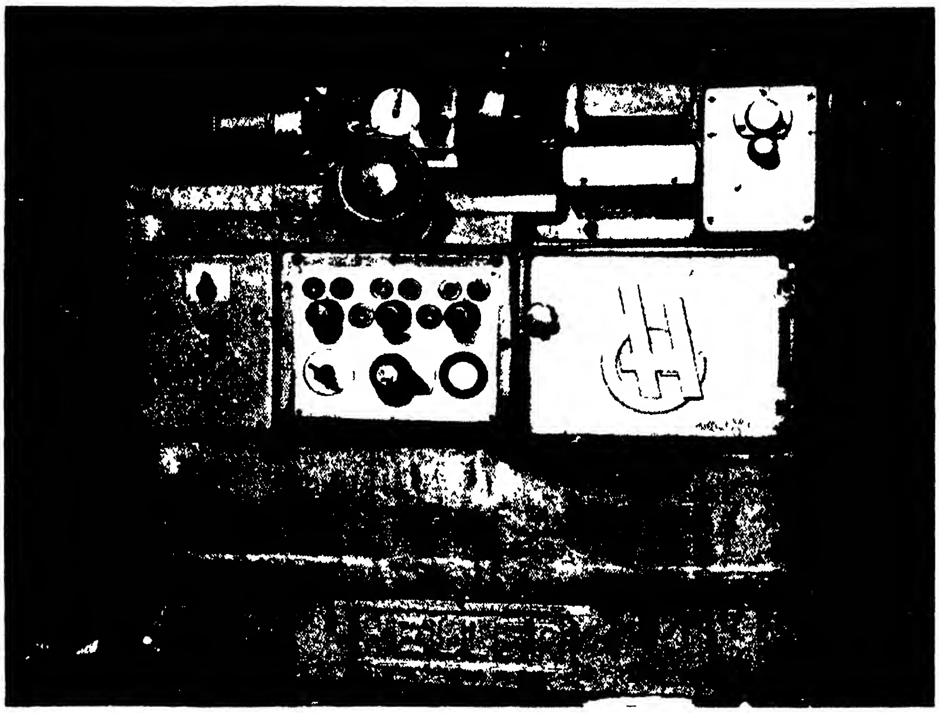
German practices indicate an emphasis upon the development of salt baths based on combinations of simple and relatively inexpensive salts. As an example, one combination for quenching consists of equal parts of potassium nitrate and sodium nitrate salts, with a melting point of about 180 degrees, C. Information on German developments in the use of cyanide salts for quenching baths may furnish small metal manufacturers and heat treating firms with specific procedures for unique treatments.

HIGH-SPEED TRIP MAGNET — Small welding shops and manufacturers using resistance welding frequently find that one of the most difficult operations in resistance welding is to make the proper electrical contact with the part to be welded. One method of processing work that was found to be successfully used in quantity production in Germany was a high-speed trip magnet that not only afforded



Samples of work produced by the German cold extrusion process. With this technique the manufacturer can fabricate many intricately shaped steel parts which could not be formed by conventional stamping procedures

This automatic thread milling machine was manufactured by Heller Brothers of Nurtingen. It weighs approximately 7,000 pounds and was valued at about 8,000 Reichsmarks



the proper electrical contact but also was of suitable strength to move the work to the vicinity of the welding machine. Magnets of this kind have been successfully used at the German firm of Semens-Schuckert on many types of work.

Another finding which has created unusual interest among American manufacturers is the remarkable die-casting machine from the Mahle works of Stuttgart. This machine, which weighs approximately 12 tons, makes magnesium castings of considerable complexity and intricacy at the rate of 80 per hour. Thousands of such castings were used during the war for radio and radar chassis. One of the 25 machines found in the plant was shipped to this country and set up for demonstration. The American Die Casting Institute and its member companies have shown great interest in it. The machine produces castings which have been thought impossible of manufacture.

Several novel machines used for continuous casting of light metals and non-ferrous alloys are described and illustrated in one OTS report on this industry. The Scovill Manufacturing Company of Waterbury, Connecticut, is using one of these machines for casting metal employed in their extrusion rod department and tube mill. The German Junghans machine used by them employs a bottomless ingot mold 12 inches deep of which the upper two inches are surrounded by a water jacket for cooling. The rate of downward travel of the ingot is controlled by rolls which engage the solid ingot as it emerges from the mold. Scovill has reported savings of several types as a result of their use of the machine.

POWDER METALLURGY — Manufacturers in the electrical components field may be interested in developing economical and efficient brushes and commutators from powdered copper and iron. The powdered copper and iron parts were only a few of the many items made from powdered metals in Germany. Their advances in powder metallurgy are described in a dozen reports

Because of the shortage of copper, Germany was unable to produce any important amounts of copper powder, but iron powder production rose from 200 tons in 1938 to 32,000 tons in 1944. Although electrolytic deposition, atomization and reduction processes were used, the bulk of German iron powder manufacture was by the "Hematag" mechanical process The most important German development in powder metallurgy was the "hot press" method. This is described in a report by Dr. Gregory J. Comstock, director of the powder metallurgy laboratory of Stevens Institute of Technology. Dr. Comstock made two trips to Germany under OTS sponsorship.

A series of machines used in Germany to produce hand sewing needles may result in the development of a new industry in the United States. The specialized equipment required for making needles has never been developed in this country Our needles have always been imported from Europe.

OTS investigators surveyed the major facilities in Germany for the production of hand sewing needles and reports containing description of processes used in the conversion of steel wire to packaged sewing needles may be obtained from the Department of Commerce office. With information on German equipment and methods American manufacturers may seriously consider the establishment of a domestic industry.

Although their production machines were often ingenious and performed economically, the Germans' machine tools were not as advanced as our own. A projection form grinding machine, a combination boring and milling machine, and swivel head vertical milling machines were three of the very few machine tools developed by the Germans.

One machine, developed by Ultra-Prazisionwerk,

has a unique optical system whereby the operator can compare a magnified image of his work directly with the design drawing as the work proceeds. The work piece is mounted in front of a lens and illuminated by an adjustable spotlight. Through a system of lenses and mirrors, the silhouette of the work is magnified 40 times and projected onto a glass screen plate. A master drawing of the work to be done, etched with acid, on cellophane or glass, is superimposed on this image.

The operation can gage the progress of his grinding work by comparing the lines of the silhouette with those of the master drawing and produce round and flat forms to a standard of accuracy equal to that achieved with limit gages.

One of the "Ultra" grinding machines was shipped to the United States and aroused considerable interest among machine tool manufacturers and producers of optical equipment. Various features of the "Ultra" grinder are described in two OTS reports.

BORING-MILLING MACHINES — The combination boring and milling machines were made to increase precision and save resetting of the work. Work was moved from one set of cutters to another. The cycle was not simultaneous but successive.

In the grinding field, OTS investigators noted a tendency to build machines with low power for a designated work swing. Ten-inch grinders, for example, would have range for full 10 inches, but power, weight and grinding wheel capacity would be more nearly comparable to our 6-inch grinders.

Profile milling seemed to have been neglected in Germany until the war started. Most of the milling machines were made by Rhorschach in Switzerland.

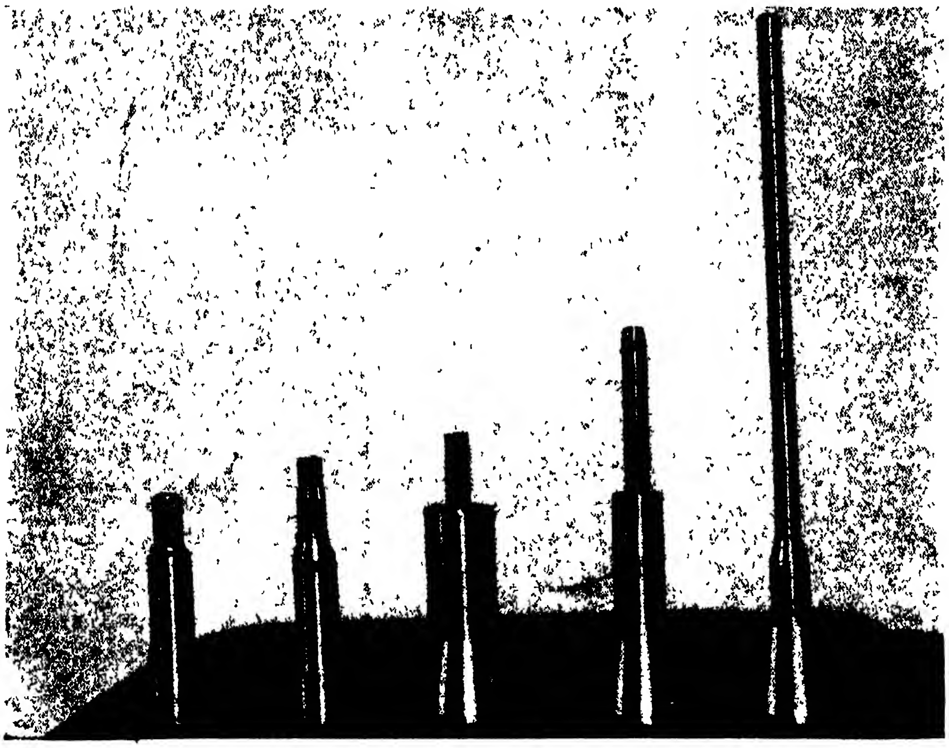
OTS investigators discovered an automatic bar chucking machine which they believe to be much more flexible than any automatic screw machine previously designed. They state that the machine, built by Alfred H. Schutte at Koln Deutz, is "very cleverly and cleanly designed" and that "in small job shops, where changes in tool setups are very frequent, a machine of this type has excellent possibilities."

The machine is equipped with four spindles and has six independently operated cross slides of the gunning type. Each spindle is provided with an individual longitudinal tool slide. The six cross slides and the four longitudinal slides are operated by individual cams through feed mechanisms which provide substantial variation in feeds without changing cams.

At the Gerb Heller Machinefabrik in Nurtingen a group of investigators found a giant machine for turn milling the crank pins and adjacent web faces of Diesel motor crankshafts. Since the crankshafts were large, it was necessary to use a 40-inch diameter cutter. Plant personnel claimed that the machine, estimated to weigh from 150,000 to 200,000 pounds, could finish a crankshaft in 24 minutes compared with two and a half hours by previous turning methods.

Abstracts of the several thousand reports on German advances released by OTS every week appear in the weekly "Bibliography of Scientific and Industrial Reports" which is published by the Superintendent of Documents and available by subscription at $10 a year.

Due to the innumerable technical discoveries which have been gleaned from a nation long prepared for war, it is difficult to immediately evaluate them in the true magnitude of their worth. Some of the smallest details may prove a great advantage to an American company. Only by a full study by our own engineers in our own plants can the true worth to American industry be determined. The reports present an unparalleled opportunity to cash in on research and discovery paid for by our enemies.



Examples of the punches used in punching extrusion and drawing operations. The Germans made considerable progress in these fields during the War

WHAT TO LOOK FOR IN FM

By David T. Armstrong

Frequency Modulation Radio Is Rapidly Becoming a Big Business. The Second of Two Articles Reviewing the Advantages of FM, and Some of the Disadvantages, for the Benefit of Prospective Buyers

FREQUENCY modulation radio, FM in common usage, is at the dawn of a new era. The demand for its unique qualities is reflected in the soaring production figures for FM receivers last year. The high quality of FM reception is in itself a compelling reason for the average listener to add an FM receiver to his household radio equipment. But what are the outstanding advantages of FM reception? The following points briefly review them:

1. *Fidelity.* FM transmitters are capable of broadcasting the entire range of audio frequencies (those that can be heard by the human ear) and FM receivers are capable of receiving this range of frequencies and reproducing them with a high degree of fidelity and with the absence of concomitant noises, hum, static and so on. A concert that is broadcast from Carnegie Hall and received in your home would sound much the same as it would if you were in the audience at Carnegie Hall.

However, not every FM receiver will give high-quality reception just because it has an FM circuit. The amplifier and loud speaker system must be of sufficiently high quality to reproduce faithfully the natural sounds transmitted. But with a quality system all along the line FM will produce the golden overtones seldom heard in regular Amplitude Modulation broadcasting, where, with the tone control set to the limit, there is too much distortion.

2. *Dynamic Range.* In ordinary radio broadcasting it is common practice to "monitor" a program before it goes out on the air. This monitoring consists in regulating the loud sounds by toning them down and bringing up the soft sounds. In AM broadcasting this pianissimo for the low sounds and fortissimo for the high sounds is necessary to bring the low sounds above the static hum and to prevent distortion of the high sounds. On the AM band the range of sounds that can be heard is relatively narrow. On the FM band there is no monitoring of the program because there is no static and the sounds sent out can cover the entire dynamic range that can be heard by the human ear. This is one of the important qualities of FM that gives the listener the presence-of-the-speaker sensation, not obtainable with AM.

3. *Static.* There is another considerable advantage to the FM receiver. While it will not eliminate static under all conditions it will reduce static

Men working on an FM "cloverleaf" antenna. This type of antenna assures maximum coverage of a given area

and radio interference, as well as the background noise produced by the radio itself, to about 5 per cent of that heard on ordinary broadcast receivers. The higher the quality of the FM circuit, the greater the reduction of hum, sizzle, crackle and static.

4. *Station Interference.* The Federal Communications Commission regards an FM station as serving an area within a radius of 60 miles. Where two stations are 200 miles apart it is then possible for them to broadcast on the same wave length without interfering with each other. With two stations broadcasting close together on the same wave length, only the stronger of the two will be heard because the FM receiver has the characteristic of selecting the stronger and suppressing the weaker of competing signals.

5. *Programs.* On February 1, the musicians' union lifted the ban prohibiting musicians from broadcasting on AM and FM simultaneously. On this date most of the major stations began broadcasting their regular AM programs on FM as well.

In addition, there are a number of stations transmitting only in the FM band which broadcast programs of recorded classical and semi-classical music. These programs are uninterrupted except for an occasional break for station identification or news. There are no commercial announcements on these stations.

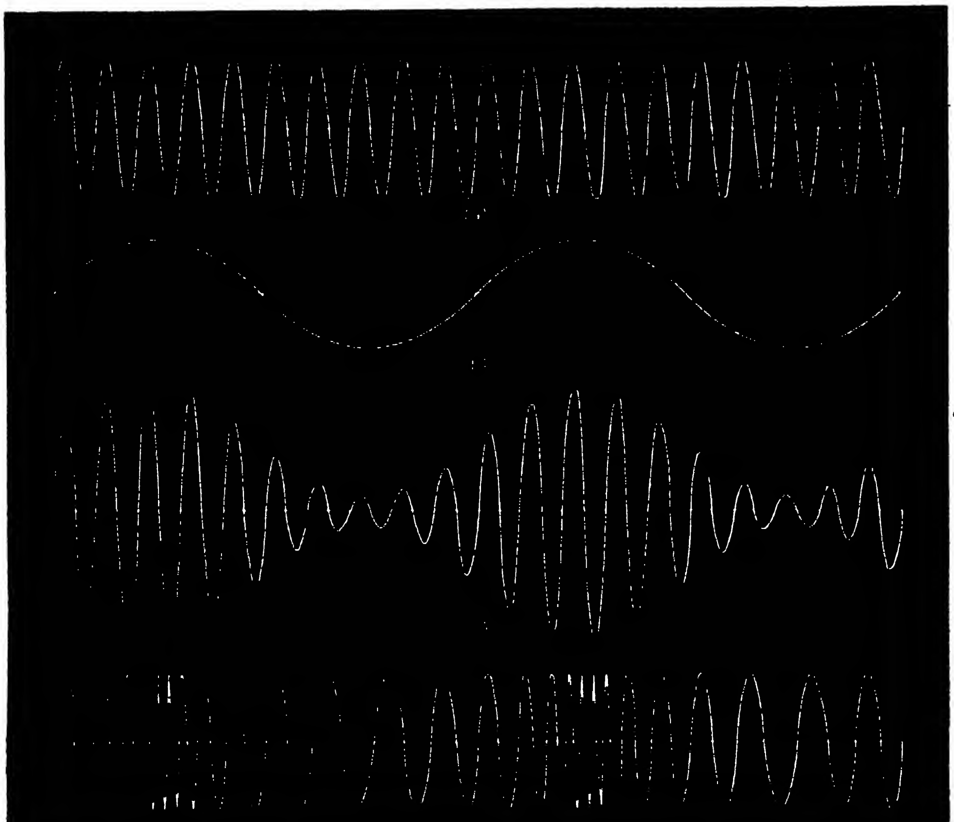
6. *Uniformity of Reception.* FM reception is uniform and constant at all hours of the day and in all kinds of weather. There is no fading of signals or increase in signal response when there is a storm or when the sun goes down.

7. *Number of Stations.* As stated above, most of the major AM stations now have FM outlets and there are quite a few stations broadcasting exclusively in the FM band. There is every indication that the number of FM stations will increase. FM stations are cheaper to set up, maintain and operate than AM stations. The band assigned for FM also makes possible a large number of stations. The nature of the FM wave is such as to make it feasible to dot the entire country with FM stations only 200 miles apart. Some school systems are already using FM radio. Witness WNYE, "the FM Voice of the Schools", in New York City. Unions are interested in FM because they have had difficulty in getting into the AM field. The International Ladies Garment Workers Union has made applications for FM stations in New York, Boston, Philadelphia, Chattanooga, St. Louis, and Los Angeles, and at least three of these applications have been granted. Moreover, this union is going after its own audience. The union's radio consultant has contracted with outstanding manufacturers for 25,000 FM receivers which are to be sold at cost to members of the union.

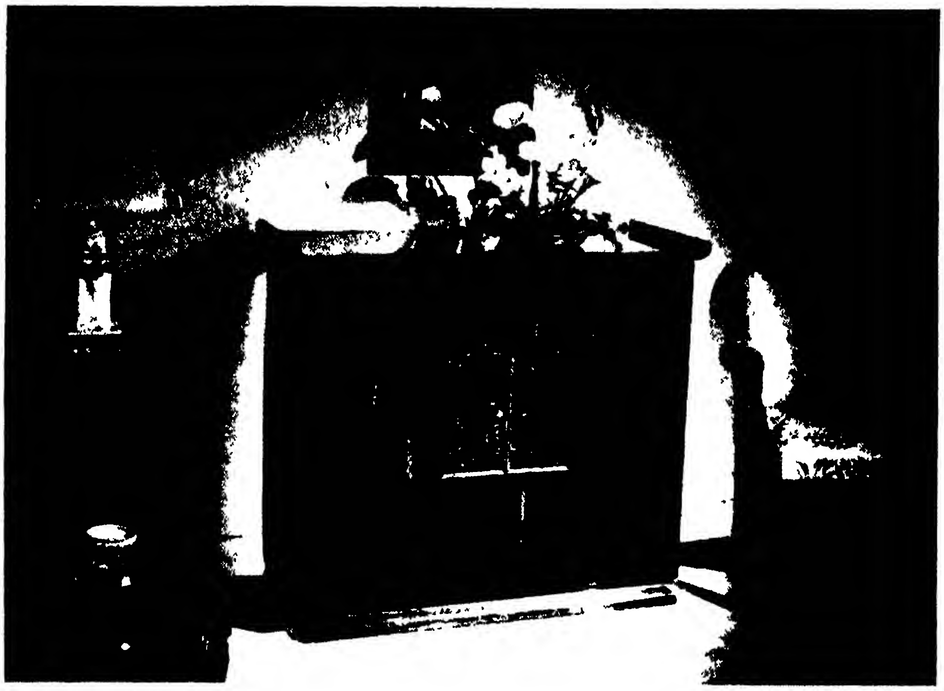
8. *Music in Factories.* FM radios are ideal for manufacturing plants which use radio to bring music to their employees because there is no distortion of the programs from the static produced by moving machinery, neon or fluorescent lights, electric motors and so forth.

DISADVANTAGES OF FM — FM is not all peaches and cream. There are some disadvantages, too, which we should consider in all fairness.

1 *Nature of the Wave.* The high-frequency wave assigned to FM moves in a straight line. It does not



Wave form (a) represents a carrier of constant amplitude and frequency. Wave (b) represents the audio signal. The strength of the amplitude-modulated wave (c) varies directly with the audio signal, while it is the frequency of the FM wave (d) that varies with the audio voltage



A console model equipped with an FM circuit. Owners of such luxury receivers form a body of listeners of unusually great purchasing power, a fact of considerable interest to advertisers

have the ability to bend according to the curvature of the earth like the waves assigned to AM. Thus, if there is a mountain or a bridge or a tall steel building between the transmitter and the receiver, reception may be difficult or impossible. Because the FM wave is a straight-line wave, it is limited principally to the horizon within sight of the transmitting antenna.

2. *Quality of the Receiver.* Not every FM receiver automatically brings the listener all the advantages of FM. There are good, medium and poor sets on the market. The built-in antennas are usually not satisfactory for any but the most ideal locations. It is generally necessary and always advisable that a separate FM antenna be installed and connected to the receiver by a high-efficiency and low-loss lead-in.

Apartment houses present a special problem because landlords object to having their roofs dotted with crosses that make them look like so many Flanders Fields. However, the Metropolitan Life housing projects in New York City will include FM antennas for approximately 13,000 families. Each apartment will be provided with aerial facilities for FM, AM and short-wave reception.

3. *Tuning Difficulty.* Tuning, an FM receiver presents a particular difficulty. A phenomenon known as "tuning drift" necessitates retuning the station shortly after the set has been properly tuned. At the present stage of FM development in tuning the push button technique is neither feasible nor desirable. An FM station comes in at three points on the dial; the middle position is the correct one.

4. *Audio Frequency Cut-Off.* Several manufacturers have been considering the possibility of making FM receivers which do not reproduce the entire range of audible frequencies. An audio-frequency cut-off at 6,000 cycles per second (as has been proposed) would mean an FM set with a tone range only slightly better than that of a good AM receiver, which can reproduce notes as high as 4,000 cycles per second. To take such a step would be to throw away one of the basic advantages of the frequency modulation circuit.

WHAT TO LOOK FOR IN YOUR FM RECEIVER— The purchaser of an FM receiver should make certain of the following important items:

1. Make certain the receiver is a genuine FM receiver, capable of delivering all the advantages of FM cited above. The basic FM circuit is the Armstrong circuit. Most manufacturers have made some slight changes in design in order to use recent developments and to facilitate manufacturing processes.

2. Regardless of the location, reception will be better with an outdoor FM antenna. Insist upon an installation that includes a suitable aerial. The built-in loops are not usually satisfactory.

3. The purchaser should make sure that he knows how to tune the FM receiver. It is not so easy as tuning an AM set. A receiver with a "magic eye" tuning device is preferable because this gives a visual indication of whether or not the receiver is properly tuned.

If the purchaser assures himself on these points he will be buying a receiver that will have good sensitivity, be free from static, and reproduce tone quality over the full dynamic range of speech and instrumental sounds audible to the human ear.

In addition to the FM outlets of the major AM networks, a live-talent network broadcasting exclusively in the FM band is now in the planning stage. The Continental Network, organized by Everett Dillard of Washington, D. C., and Major Edwin H. Armstrong, the guiding genius of FM, ties up Washington, Alpine, N. J., Rochester and Buffalo on a telephone hook-up. This same network also includes nine other FM stations in New York, Connecticut, Massachusetts and New Hampshire which merely rebroadcast FM programs from FM receivers. One of the decided economic advantages of FM over AM in the network problem is that in AM a wire connection between two stations is mandatory because AM signals picked

up by air and rebroadcast amplify and transmit all the static, fading and distortion.

It is quite possible that FM network operation will be generally less expensive than comparable AM network operation. FM transmitters, as stated previously, are cheaper to install, operate and maintain than AM transmitters. Dollar for dollar the broadcaster gets more out of his FM transmitter than from his AM. The concept that FM will not and cannot compete with AM in the network field is not so glibly accepted as it used to be.

For some time now radio sponsors have been thinking seriously about the large sums of money they spend for their AM network programs. They know that much of the AM network appeals to the mass audience that does not have too great a purchasing power. They know the FM market is a quality market. A man who spends several hundred dollars for a quality set is a potential customer for other quality goods. Furthermore, the man who purchases an FM receiver will be listening to it.

MORE AND MORE FM TIME — More and more time is being sold on FM. It is highly probable that in 1948 FM networks will be right in there fighting the AM networks for business in a field where there has not been much competition. Milton Sleeper, editor of *FM and Television,* makes the interesting suggestion that the FM networks might buy up live-talent shows and sell the time. Thus a $20,000, half-hour show could be bought up by 200 FM stations. Each would put $100 into a kitty or pay a pro-rated figure on the basis of area coverage! This would be one way of appealing to the high-quality local advertisers.

All the channels in the AM band are now in use and there is no possibility of assigning any new frequency to a newcomer. There are about 1,200 stations in the entire AM broadcast band and "that's all there is, there ain't no more." This is obviously discouraging to the would-be broadcasters who came late. It is also hard on buyers of time because the wealtheir customers have been able to monopolize select spots in the AM band and to dominate the most desirable periods of AM time.

But all is not lost. FM is throwing open this closed door to individuals, organizations, schools; to anyone who cannot find room in the AM band. There is room for about 4,000 stations in the FM band. Compare this with the 1,200 stations in the AM band and their concomitant overlap causing dissonance and static.

The entire radio industry is involved in the growth of FM. Whatever the system, obviously, the radio industry wants to sell radios. Whether these should be FM or AM radios may be resolved from the sage remark made by one observer: "My answer is that if you want to hear Toscanini, buy an FM set. If you want to hear Bob Hope, get an AM set." An FM enthusiast recently came up with the rebuttal: "If you want to hear Bob Hope at his best, ask your local station to put him on FM!" But the over-all advantages of FM have been better summed up by another FM admirer: "The thing that I like best about FM is not what I hear, but what I don't hear. I appreciate most its freedom from static, freedom from cross-talk, freedom from interference and freedom from distortion. With these bad features of ordinary radio erased by FM, the service is wonderful."

An FM receiving antenna. Regardless of the location of the receiver, a proper FM antenna and a low-loss transmission line are necessary for the most satisfactory reception

THE SETTLEMENT OF CANADA'S NORTHLAND

Using Modern Methods of Living in an Inhospitable Environment, Its Population Grows with the Demand for Its Resources

By Harry Chapin Plummer

THE NORTHWEST Territories and the Yukon together comprise approximately one-third of the total area of Canada. Lying in the Northwestern corner of the Dominion, this great expanse was long a virtual no-man's-land peopled by a few nomadic Eskimos and Indians with a sprinkling of traders, trappers, prospectors, missionaries and Royal Canadian Mounted Police.

Now, however, this region is taking shape as an important industrial area. Even the Arctic Sea is beginning to figure in terms of maritime trade. In 1944, 97 vessels—an aggregate of 58,179 tons—entered ports in the Yukon and Northwest Territories. Seven of these were in foreign service. The remaining 90 were operating in the coastal service. In the following year the Royal Canadian Mounted Police boat, "St. Roch," succeeded in navigating the Northwest Passage, both from east to west and west to east, thus setting to rest the time-honored legend that marine traffic on the Arctic Sea would never be possible. In 1946, some 120 port entries—an aggregate of 75,863 tons—were recorded.

The steadily increasing industrialization and settlement of the Canadian Northland is due, to a considerable extent, to the recent improvements in transportation facilities (the "snowmobiles," the "tractortrains" and air transport) and to the use of modern telephone and radio equipment.

Another reason for the rapid development of this region is the fact that its waterways afford easy access to the sea from May through to October. The Mackenzie River is navigable for 1,300 miles through Canadian territory to the Arctic Sea. The Yukon River, 1,979 miles long, is navigable for 1,400 miles through the Yukon and Alaska to the Behring Sea.

CLIMATE — The scene of this increasing settlement and infant industrialization is located in the West-

A maintenance camp on the Alaskan Highway. Transportation facilities in the Northland are constantly improving

Cutting a new road in the Northwest Territories

erly portion of the Northwest Territories and the entire Yukon. The climate of this area benefits from the same influences—although in lessening degree as one moves northward and farther inland—that are found along the entire Pacific Coastal region from California to Alaska. Warm air currents from the Japan Stream follow the river courses and canyons across the Alaskan mountains into neighboring Canadian lands and there meet the masses of cold air flowing down from the Polar regions. This results in a milder winter climate and in summer temperatures which are comparable to those of the Maritime Provinces to the south.

Beyond the eastern limits of the Mackenzie Valley in the Northwest Territories this dispensation of nature ceases. The climate of the intervening country to Hudson Bay and on through New Quebec (the former Ungava) and Labrador to the Atlantic Ocean is far more harsh and the terrain shows the resistance to timber growth that is characteristic of the more northerly latitudes. The southern coasts of Hudson Bay (55 degrees, North) and James Bay (51 degrees, North) are subjected to far lower temperatures than are Aklavik and other settlements around the Mackenzie Delta (from 68 to 70 degrees, North).

ELDORADO MINES — Near the Arctic Sea on the 65th parallel are the Eldorado Mines, second of the world's major supplies of pitchblende—source of radium and uranium. The mine's present personnel numbers 300. And when the mines reach full production a working force of 500 is anticipated. Future developments, whether of peace or of war, may render these mines a vital center of production for the Dominion.

More than 20 per cent of the total mineral production of the Northwest Territories between 1943 and 1946, valued at over $23,714,048, was credited to the pitchblende deposits mined by the Crown-controlled Eldorado Mining and Refining (1944) Limited, Bear Exploration and Radium, Limited, and other subsidiary units of the state corporation. The balance was divided: gold, $15,068,991; silver, $842,000; petroleum, $1,932,104; natural gas, $3,260; scheelite, $37,674; copper, $24,102.

The gold yield came almost entirely from the mines in the vicinity of Yellowknife, which is approximately 270 miles south of Eldorado. Yellowknife is a "boom town" transformed into a permanent, substantial community with a remarkable variety of secondary industries and concomitant crafts and trades. Among the major improvements now in progress is the Snare River hydroelectric power project, at the outlet on Big Spruce Lake, some 90 miles northwest of the settlement. When it is completed late this year, the plant will have a capacity of 8,000 horsepower in two power stations. Total expenditures in the development of the planned town are authoritatively estimated at $1,000,000. Construction of many large buildings is already well advanced, and it is expected that the majority of these will be completed by late spring.

The potential water power resources of the Northwest Territories and the Yukon are conservatively estimated at 430,000 horsepower under conditions of normal flow, and at 840,000 horsepower for the open half year when the ice and snow melt.

LUMBER — As at many other settlements in this "Western Arctic," Yellowknife is the scene of a steadily growing lumber industry. Timber cut in the region includes white and black spruce, white birch, tamarack, aspen and balsam poplar

Another Yellowknife industry is fish canning. Lake trout and other varieties of fish are canned at a plant on the shores of the Great Slave Lake. Some 1,500,000 pounds of fish are shipped each year from this cannery to Canadian and United States markets.

Mining has displaced fur trapping as the top industry at Yellowknife, as it has at most other centers in this region. Nevertheless, pelts to the value of $14,000,000 were taken between 1940 and 1946 over the Northwest Territories alone.

NORMAN WELLS — The community of Norman Wells has a population of 375 It is another fast-growing industrial center. Located close to the 65th parallel, it is the site not only of a veritable lake of oil, but also of the most northerly petroleum refinery on this continent. The production of this refinery increased from 20,191 barrels in 1939 to 181,408 barrels in 1946. Distribution from the Norman Wells plant is maintained by bulk agencies at Fort Smith, Fort Simpson, Yellowknife and Aklavik. From Aklavik deliveries are made by steamers and schooners to Arctic shore points as far east as Coppermine, Holman and Reid Islands.

Problems posed by the climate of the Canadian North—even by the relatively mild climate of the Western Arctic—have activated intensive research and experimentation on the part of the Army and other government agencies in close coöperation with industrial and commercial interests. Many valuable innovations and devices have resulted from the combined efforts of these forces, particularly in the fields

of clothing, housing, insulation of water and sewer pipes and central heating.

Exhaustive studies of clothing most satisfactory for wear in the extreme cold have produced, among other items, a primary undergarment known as the "string vest." Developed by the Army, it is designed to be worn next to the skin, covering the torso. This string vest's wide mesh holds regular underwear clear of a perspiring body and permits a circulation of air next to the body to evaporate the perspiration. The weave of the vest is as coarse as that of a herring net. In fact, the idea was adopted from the Norwegians who have long used actual fish net next to the skin to guard against perspiration-soaked clothing in low temperatures.

Careful observation of the materials and methods employed by the Eskimos in building their igloos and other dwellings led the Army to the development of a "hutment" which provides housing for 20 soldiers. This prefabricated, demountable building is light enough to be transported by air. It is made of plywood panels with rock wool insulation and an aluminum foil moisture bar. Blank panels are interchangeable on walls and roof. Door and window panels are also provided. By the use of additional panels, a hutment can be expanded to a mess hall, administration building, store or hospital. The side walls of the hutment are made stable by notched recesses in the truss ends, with the end walls tied together by the roof frame. The individual wall, door and window panels are held firmly together by a bolted top plate. Panel joints are waterproofed by rubber mastic which does not hinder dismantling the hut, even if it has been painted.

A condition which greatly hinders the construction of permanent buildings in the Canadian Sub-Arctic Zone is the permafrost—a layer, or layers, of soil which remain permanently frozen. The surface of the ground thaws in summer to depths depending upon the length and warmth of the season. The depth of the "active layer" ranges from one foot to six or eight feet and the depth of the permafrost varies widely, even within a small area Three methods of building have been analyzed thoroughly, and the results follow:

1. Conventional foundations last only a short time, as the heat from the building upsets the permafrost balance and subsidence follows. Buildings put up at various posts, such as Whitehorse and Norman Wells, during the war, have now taken on a "snake-like" appearance.

2 Some success has been attained by "floating" buildings on top of the muskeg, which provides a natural insulation without disturbing the permafrost. Insulating the floor to prevent building heat going into the ground has proved unsatisfactory for heavy buildings.

3. The method most satisfactory for permanent building appears to be the erection on piles—wood, pipe or concrete—permanently frozen into the ground about one and one half times the depth of the active layer. The upper portions of the pile are lubricated so that the active layer can expand and contract without disturbing the piles.

Frame buildings, well insulated by any one of various methods are the normal type of construction. Materials for this sort of building are easier to transport and to fabricate. In addition, until entirely satisfactory foundations are found, to use more rigid materials is to invite risk of cracking due to uneven settlement.

WATER AND SEWAGE PROBLEMS — Normal problems of water supply and sewage disposal are greatly complicated by the extreme cold, by permafrost and by the fact that many lakes freeze to the bottom during the winter. At Chirchill, scene of the Army experimentation, a large heated tank is used for water supply and the water is circulated continuously as an additional safeguard against freezing.

Above ground, pipes are carefully insulated, and steam is introduced at intervals. Heated corridors connect many of the buildings. These corridors house the utilities which are grouped together so that heating mains keep water and sewer systems from freezing. Due to the permanently frozen sub-

Removing the roof from one of the Canadian Army's demountable, prefabricated "hutments." The demounted hut is light and small enough to be transported by air

soil, conduits and pipes cannot be laid below ground.

In the Western Arctic a tremendous range of ground conditions—from great rock outcroppings to swampy muskeg and permafrost—are encountered. Gradually, however, the Army engineers have succeeded in overcoming many of the natural difficulties presented for vehicular movement. During the war special tracked vehicles known as "snowmobiles" were developed for operating over snow. The northward trek of "Exercise Musk-Ox" in 1946 brought these conveyances into first real service test. From that demonstration was evolved "Penguin Mk. 1," the good performance of which was followed by "Penguin Mk. 2," also utilizing the basic "snowmobile" chassis. This vehicle is now being produced by a Canadian manufacturer.

A simultaneous civilian development is the "tractor-train", upon which the government, mining and other private commercial interests now depend for low-cost hauling of supplies for a midwinter period of about one hundred days, beginning around January 15th when the lake ice is sufficiently thick to support heavy freights. A standard tractor-train consists of a $10,000 tractor pulling twenty-eight 15-ton sleds and a caboose. Difficulties occasioned by breakdowns usually call for a new tractor each season. The "train" is manned by two drivers, two brakemen and a cook. Running for the full 24 hours, the trains haul from 100 to 125 tons of freight and average about fifty miles per day. They operate from Waterways and Whitehorse—railheads for traffic destined respectively to the Mackenzie Valley in the Northwest territories and the Yukon. The tractor-train can climb only the slightest grades and rough ice on the frozen lakes is an ever-present problem. Because of the varying thicknesses of ice, rivers are avoided as much as possible.

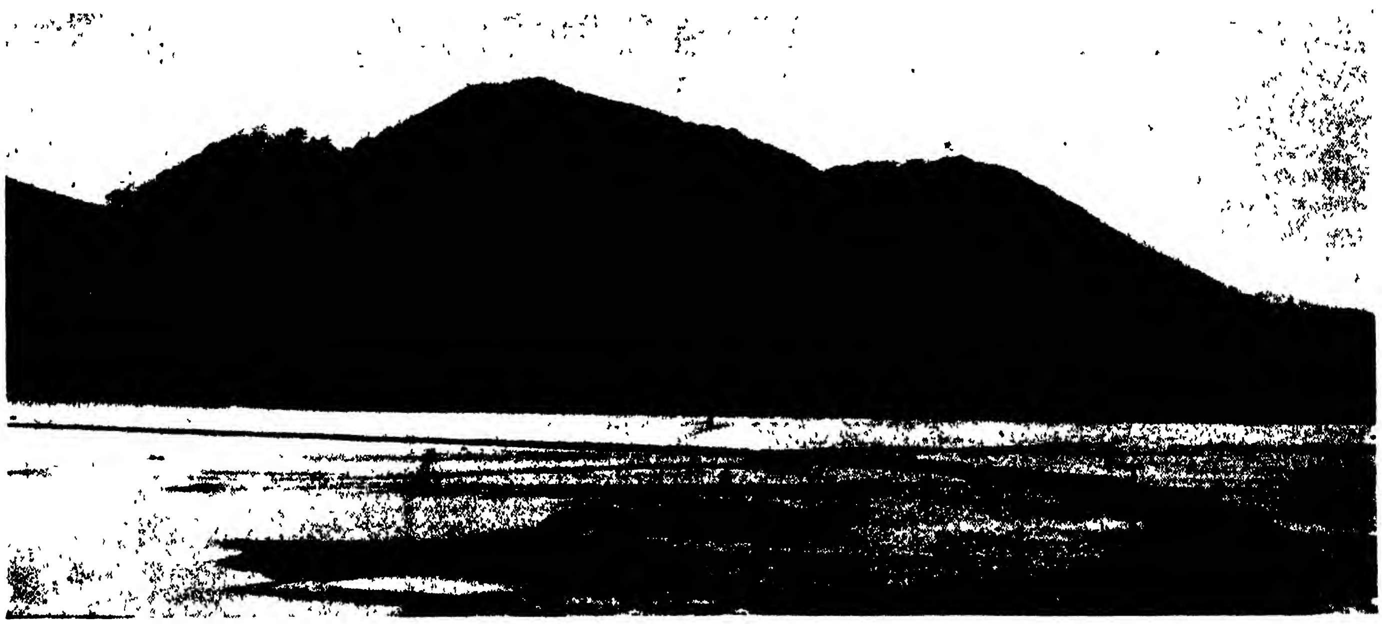
The Army is now doing considerable work on the winterizing of vehicles—both wheeled and tracked to adapt them for operation at low temperatures. Since much of the research is being pursued by the same manufacturers who produce civilian equipment, the work eventually must benefit civilian vehicle users. Such items as fuel, lubricants, batteries, heaters, anti-freeze, rubber components and structural material failures resulting from low temperatures and high stresses developed, by driving through deep snow over frozen ground and rutted roads, are receiving close scrutiny.

RECLAIMED ANTI-FREEZE — Recent emergency calls from the Alaska Highway of the Northwest Highway System (the Canadian portion of the former "Alcan Highway") for supplies of anti-freeze disclosed the fact that 7,000 gallons of water-glycol mixture had been drained from Army vehicles throughout the Dominion earlier in the year and that 3,000 gallons of glycol had been recovered by re-distillation at the Defense Research Council Laboratories in Ottawa. Two years ago approximately 10,000 gallons of glycol were recovered and re-inhibited by the laboratories for the Royal Canadian Air Force by this same economical process.

Many civilian agencies would be benefitted greatly if suitable vehicles were available for year-around land transportation in the Western Arctic. No single agency could afford to do the developmental work. However, when that work has been done by the Army, and adequate sources of manufacture have been established in Canada, many types of vehicles for such purposes can be produced for civilian interests. This equipment will be extremely valuable for rural mail delivery and for rural doctors, for police patrol vehicles, prospectors, surveyors, for timberlimit vehicles, and for rescue work, to name only a few of the possible applications.

The steady influx of families from the Canadian Provinces and the increase of those already located in the Northland constitute a powerful incentive for the armed services, various government departments, many civilian agencies and private interests to improve conditions, mitigate the hardships and eliminate the dangers of the Western Arctic. Through their efforts this once-inhospitable wasteland is rapidly gaining commercial and industrial importance.

Good highways and telephone and telegraph lines lace together Canada's Northland



VACUUM METALLURGY

Melting Metals in the Absence of Gases Produces Materials Which Are Purer, Denser, Tougher and More Ductile

By Harold A. Knight

ARISTOTLE is reputed to have said that "nature abhors a vacuum." But the scientist and engineer have often found the vacuum a useful friend The ordinary citizen has found it serviceable in such articles as the vacuum bottle for a picnic and for the radio tubes in a portable set which is turned on after the scrap papers have been picked up and the checkered tablecloth folded.

By vacuum metallurgy, metals are made gas-free, porosity-free, denser, tougher and more ductile. What has been largely a laboratory or pilot plant process is now evolving into a full-scale commercial process. One of the most recent applications of vacuum metallurgy involves production of a new group of super-alloys such as those which must withstand high temperatures in the engines of jet aircraft.

A typical alloy of this type contains 60 per cent chromium, 20 per cent molybdenum, the balance being iron. This alloy must be melted and cast in a vacuum. In preliminary tests it seems better than the cobalt-base alloys, used so widely during the war, giving promise of safe use at higher stresses.

In speaking of this new chromium-base group of super-alloys, refined by vacuum metallurgy, Dr. Clyde E. Williams, director of the Battelle Memorial Institute, says that they will withstand higher temperatures and pressures than materials now available and so will offer potentialities for power generation that are "simply staggering."

Vacuum metallurgy was employed to produce nickel-chromium alloys in Germany as early as 1938. The Germans made batches of alloys up to 10,000 pounds, finding that alloys made by this process have properties which cannot be duplicated by any other means. During the war lithium metal was reduced from its ore, spodumene, in a single operation and at a cost less than half its then-current market price. It was a useful process in producing metallic magnesium from dolomite, supplementing production from Michigan brines or sea water from the Gulf of Mexico. In the ferrosilicon process, where dolomite is mixed with iron, a high vacuum is necessary to lower the temperature of distillation. One of these wartime ferrosilicon plants has been partially converted to production of metallic calcium, again in high vacuum.

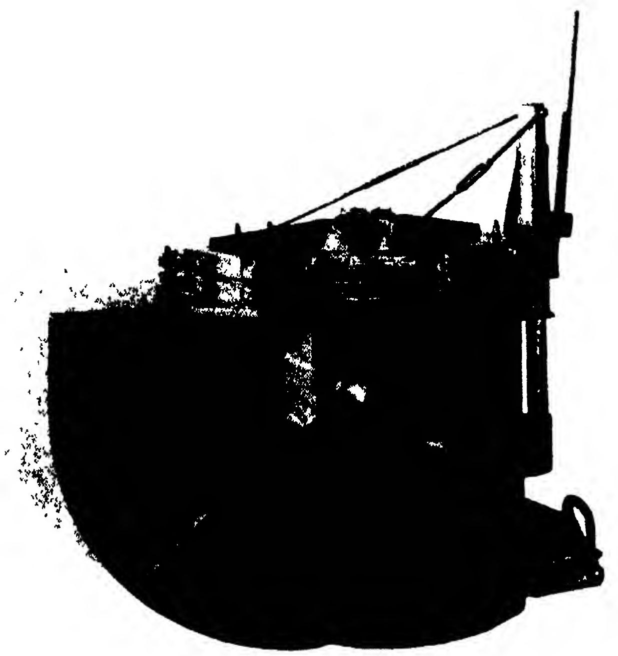
EARLIER EXPERIENCES — In Germany Dr. Rohn has applied vacuum melting to many alloys used largely in the electrical industry, with furnaces up to six-ton capacity. In this country, Sweden and England vacuum melting on a smaller scale has become quite common in connection with high-cost materials requiring high purity and freedom from small amounts of carbon, oxygen, nitrogen and hydrogen. When a vacuum furnace was operated experimentally at the University of Illinois from 1912 to 1916, it was demonstrated that the magnetic properties of iron and iron-silicon alloys could be greatly improved by vacuum melting, the carbon and oxygen being eliminated. Work was continued at Westinghouse research laboratories from 1916, the results laying the foundation for the Hipersil alloy used in Westinghouse transformers since 1940. The company is now applying vacuum melting to some new magnetic alloys which look very promising. Here it appears that the process may soon be applied commercially.

Most laboratory furnaces will handle only about 10 grams of metal at a time, but installations have recently been set up that will handle charges of 300 pounds and more. A Westinghouse expert stated recently: "I believe that before long we shall see 1,000-pound vacuum furnaces in operation in this country, to be followed by even larger ones."

The theory of vacuum work is fairly simple. Almost everyone is familiar with the fact that eggs will boil on a mountain top, where atmospheric pressure is considerably lower than at sea level, at considerably under 212 degrees, F., water's normal boiling point. In a high vacuum, metals may therefore be made to volatilize at temperatures as much as 1,850 degrees, F., below their normal boiling point.

The normal atmosphere of the earth at sea level supports a mercury column 760 mm high, with pressures read in millimeters and microns, the latter being a thousandth of a millimeter. In present-day vacuum furnaces pressures as low as one micron (1/760,000 atmospheric pressure) are obtained.

Not only are the metals melted in a vacuum, but they are cast within the furnace. The removal of the molten metal from the vacuum into the atmosphere would expose the metals to the various gases which should be eliminated. Ingenious devices provide for pouring the highly heated metal (perhaps as hot as 3,600 degrees, F.) into the molds. In some cases the furnace tilts and pours into a mold that is pivoted and remains upright. In other instances a plug made



A tilting vacuum melting furnace

of the metal being melted is placed in the melting chamber. At the proper time this plug is melted out by an induction coil and the metal allowed to flow through the hole into the mold.

High vacuum is maintained by two types of pumps: (1) a "roughing" pump which exhausts the main body of air and (2) a finishing or diffusion pump, the latter containing oil or mercury. The flowing oil brings out any "tramp" air and effectively seals the chamber against any back movement of air. Heat for the melt is applied by an high-frequency electrical induction unit. Furnaces are sealed at key points with rubber gaskets augmented by rubbery or plastic compounds where necessary. Often there are windows in the melting chamber so the operation may be observed.

As no slagging can be carried out in a vacuum furnace, the process is primarily one of melting, with elimination of gaseous and volatile impurities. Solid impurities are often reduced by special heat treatment before metals are introduced into the vacuum furnace. In the case of copper, it is sometimes desirable to take out such impurities as sulfur, selenium, tellurium and arsenic.

The principal metals which have thus far been studied by vacuum treatment are iron, copper, nickel, aluminum, chromium, manganese, calcium, barium and cesium. Copper treated by vacuum metallurgy is gas-free and purer than the best commercial copper. There is better density and soundness, a better electrical and thermal conductivity and a marked increase in ductility.

The National Research Corporation of Boston made some comparisons between the best commercial copper and vacuum-cast metal. The former contained hydrogen to the extent of 0.00012 per cent. The vacuum cast contained only 0.00001 per cent. As to oxygen, commercial copper contained 0.00045 per cent as against 0.00039 per cent for vacuum-cast. For other gases, comparisons ran to 0.0004 and 0.00002 per cent. Sulfur compared 0.0023 to 0.00006 per cent. As to the physical properties of the two types of copper, the vacuum-cast proved superior to the commercial, except in tensile strength. Here the two tied at 54,500 pounds per square inch. In density, commercial measured 8.922 grams per cubic centimeter against 8.930 for the vacuum-cast. The elongation was 17.3 compared with 20.3 per cent. Reduction of area ran 76 and 88 per cent. Electrical conductivity was 99.4 IACS for the commercial against 100.3 for the vacuum-treated.

Engineers have made good progress in development of vacuum-cast nickel. This has a much lower hardness value than the purest nickel now available. It can be supplied in 100-pound ingots that are very pure, soft and ductile, a metal which should be ideal for vacuum tubes in radios and other electronic devices. Such nickel is comparable with the highest quality nickels reported in metallurgical literature, exhibiting neither hot nor cold shortness in forging or rolling.

Aluminum has not been treated as successfully as other metals because of the perpetual oxide coatings on the metal. However, research has gone far with pure iron, 100-pound ingots having oxygen under 0 05 per cent, nitrogen as low as 0.0005 per cent and carbon under 0.005 per cent. It is an extremely homogeneous iron which is suitable for magnetic applications and for samples of perfect iron for spectrographic work, where the unknown is compared with a known sample.

Work on de-gassing chromium for high-temperature applications, as previously mentioned, seems very promising. Decreasing the oxide and gas content of chromium by vacuum sublimation results in purity of 99.95 per cent. Such chromium can be shaped by ordinary lathe methods and can also be somewhat deformed without fracture by hammer blows.

As already indicated, metals in vacuum furnaces may be made to volatilize at temperatures hundreds of degrees below their normal boiling points. When a volatile metal is contaminated with a metal of lower volatility, a separation may frequently be accomplished by vacuum distillation. Calcium is purified commercially in this manner. Manganese and chromium have been purified at 3,650 degrees, F., and at pressures as low as 10^{-4} mm. In short, the impurity is distilled off. Selenium, tellurium and sulfur can thus be distilled off copper. Zinc can be distilled off from brass scrap, leaving only copper. Sodium, potassium and lithium could be separated by a fractionating column, if necessary.

VACUUM CASTING — The experiments and commercial techniques in vacuum casting so far involve casting permanent molds and molds of the precision investment casting type. Forming of metal by forging, rolling or drawing in a vacuum is untried, apparently, and the possibilities are unknown. Ordinary sand casting is impractical in a vacuum. In older casting techniques the mold was lined with carbon or some similar mold wash, but this introduced carbon and other foreign elements which interfered with the purity of the product. Engineers of National Research Corporation chill the castings with water or

argon gas circulating around the molds, thus preventing solidified metal from adhering to the molds.

The applications of vacuum metallurgy besides those already mentioned are in the manufacture of radio tubes, magnetrons and various glass-to-metal seals. In such uses experiments have already been made. Other proposed uses are in the manufacture of thermocouple wire, precision resistor wire, aluminum collapsible tubes and many other applications where the ductility needed for deep drawing is essential.

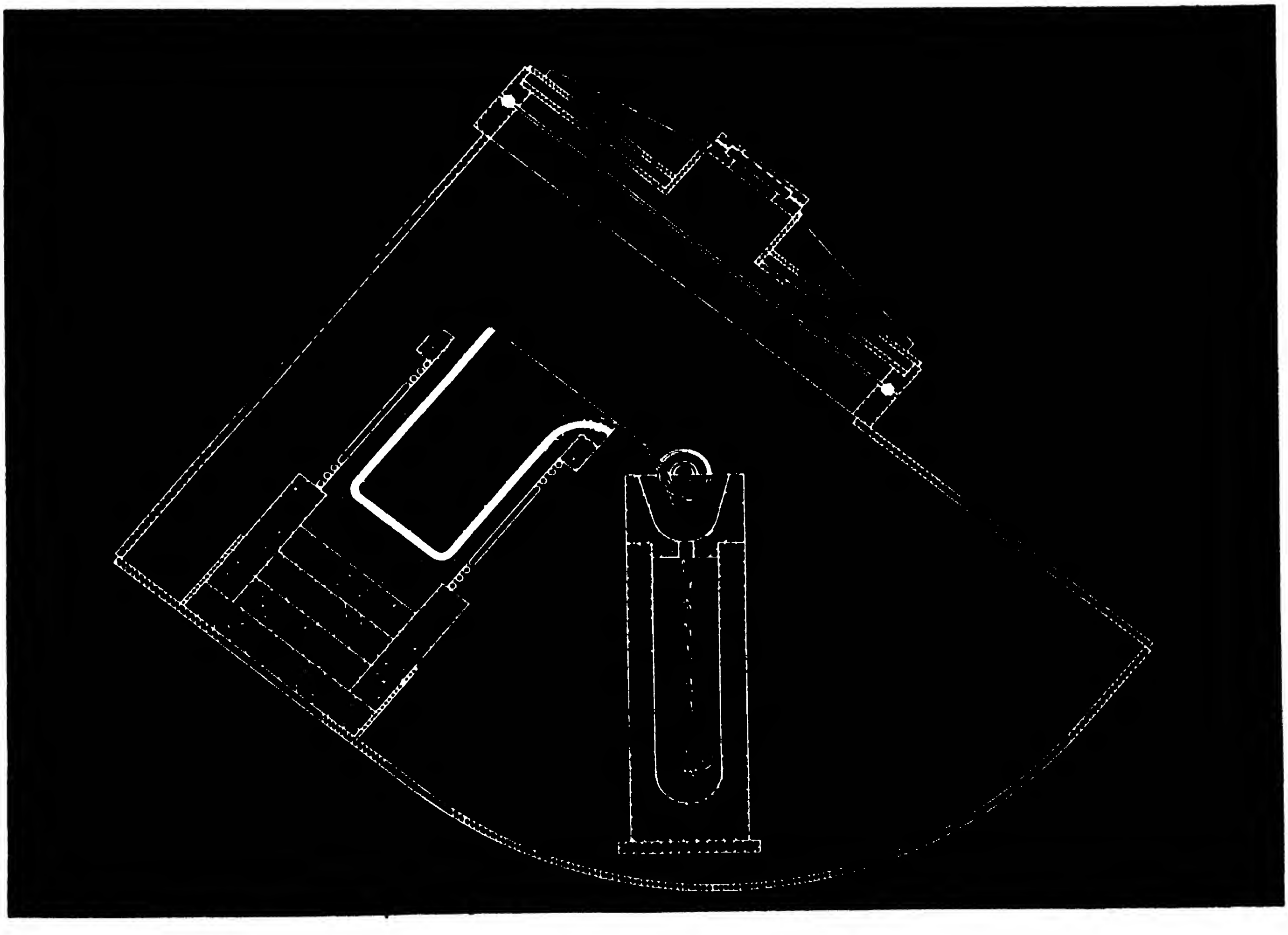
According to one authority, vacuum metallurgy is particularly well suited to the preparation of iron-nickel and iron-cobalt alloys because of the inherently high cost of these products. In other words, a material that is already high in cost to start with, can absorb a little more expense for perfection. An expert who has worked with this technique for several years estimates costs as follows: For a 1,000-pound charge which is melted down and poured once every hour, using five men and equipment costing $100,000, the cost would be between two and four cents per ingot on a continuous production basis. This is not at all prohibitive for alloys costing over 10 cents per pound for raw materials, particularly taking into account the fact that vacuum metallurgy can produce ingots practically without a "pipe" (a hollow caused by shrinkage in cooling).

Another expert has estimated that the cost of vacuum treatment adds from one to 10 cents per pound to the selling price of metals. Ordinary copper sheet now sells at around 33 cents per pound. The five cents added to the cost by vacuum treatment represents no significant increase in price for improved qualities. There are in fact six basic fields in which vacuum metallurgy is now, or can be, applied: Preparation of metals from ores and compounds, purification and degassing of ingot metals, casting, forming of solid metals, heat treatment of solid metals and finishing of surfaces. It is proposed to explore vacuum furnaces for certain forms of heat treatment such as bright annealing. The surface degassing of electronic tube parts has already been accomplished.

Hand in hand with developments in vacuum metallurgy goes progress in other fields using the vacuum treatment. One of the latest applications is a dehydration process for conversion of orange juice to a powder, in which the water content is reduced from 90 per cent to under 1 per cent. Water is removed from penicillin by the same technique. High vacuum is also used to bring about dehydration of blood plasma. It can also concentrate and isolate vitamins in pure form. Plastic sheets are being metallized by aluminum and other metals to form effective reflectors.

Vacuum metallurgy, then, is another versatile addition to the tools of modern technology.

Diagram of the tilting vacuum furnace. The mold remains vertical as the furnace tilts and the charge is poured



SCIENTIFIC AMERICAN'S Industrial Digest

X-RAY THICKNESS GAGE

Steel Strip Measured Continuously As It Comes From Rolling Mill

THE X-RAY thickness gage is an instrument which can measure the thickness of red hot steel without physically contacting it in any way. The device shoots one X-ray beam through the hot steel strip as it moves off the finishing stands in a rolling mill. Simultaneously a second X-ray beam from the same source penetrates a standard reference sample of steel which is known to be of the desired thickness. The instrument then measures and compares intensities of the two beams. If the two intensities are equal the steel strip is of the desired thickness. A difference in intensities indicates that the strip is either more or less than the desired thickness, and the amount of deviation is automatically noted by the instrument. The thickness gage takes measurements continuously while the steel strip is moving.

Traditional methods of measuring strip steel necessitated waiting until the steel had cooled from a temperature of 1,400 degrees, F., and higher to a temperature at which a micrometer might be held manually against the steel. Since the steel strip moves at speeds as high as 2,000 feet per minute, six tons or more of off-measure steel might be rolled under conventional measuring techniques before the error was determined and corrected.

Developed by Charles W. Clapp and Raymond V. Pohl in the General Electric Company's General Engineering and Consulting Laboratory, the X-ray thickness gage already is in use at the Irvin Works of the Carnegie Illinois Steel Company.

Although specifically designed for measuring the thickness of hot-rolled steel strip, the instrument should be adaptable to other industrial applications in which a non-contacting gage is desired.

DIAMOND-CHIP AMPLIFIER

Electron Bombardment of Crystal Yields High Current

SMALL diamond chips, bombarded with a beam of electrons, have been found to yield electric currents as much as several hundred times as great as the original beam. This radically new method of amplifying an electric current may have a far-reaching influence on the future of electronics. It holds promise of opening up an entirely new approach to the design and use of certain types of electron tubes. Also, it is expected to be of considerable theoretical value, since it provides a new and powerful tool with which scientists may learn more about the fundamental structure of solid matter and how it behaves under the impact of electrons.

This technique, developed by Dr. K. C. McKay of Bell Telephone Laboratories, grew out of earlier work by Doctors D. E. Wooldridge, A. J. Ahearn and J. A. Burton, also of Bell Telephone Laboratories. Essentially, their work consisted of causing an insulating material—which by definition will not conduct electricity—to carry considerable amounts of it by means of electron bombardment.

Dr. McKay, using a diamond chip as the insulating material, has reported that electric currents shot at the chips have been amplified as much as 500 times.

Inducing electric currents in diamonds by electron bombardment proved to be a difficult matter. One of the major obstacles was encountered when it was learned that as the current started to flow in the diamond chip, electrons became trapped in the tiny imperfections which are present in all crystals. Thus, after the first fraction of a second, the induced current tended to waste away under the opposition of the trapped electrons. To overcome this, an alternating voltage (60 cycles per second) was applied to the diamond chip. Alternately negative and positive charges thus were drawn through the crystal and some of each were trapped. The trapped positive charges canceled out the effect of the trapped electrons and the current induced by the electron beam was allowed to flow freely.

The diamond crystals used in these experiments are small chips or even so-called "saw-cuts" obtained from a natural diamond in shaping it for a gem stone. The chips average

The diamond crystal mounted in this ceramic socket has been found to yield currents as much as 500 times greater than the electron beam which bombards it

a quarter of an inch square and approximately 20-thousandths of an inch thick. Most of the chips give satisfactory results, although some of them do not respond at all.

Before a crystal is ready for use, gold is evaporated onto its flat surfaces in films less than a hundred-thousandth of an inch thick to afford good electrical connections.

In bombarding the diamond chips, successive pulses of electrons lasting approximately a microsecond are used, rather than a steady current. Energies of 15,000 electron volts are employed.

One of the most important features of this new technique is that the induced currents are produced within exceedingly short times. In fact, the time required is so brief that thus far it has not been possible to measure it. However, it is estimated to be less than one ten-millionth of a second.

Dr. A. J. Ahearn, Bell Laboratories Engineer, places a diamond chip in a test circuit

MOISTURE DETECTOR

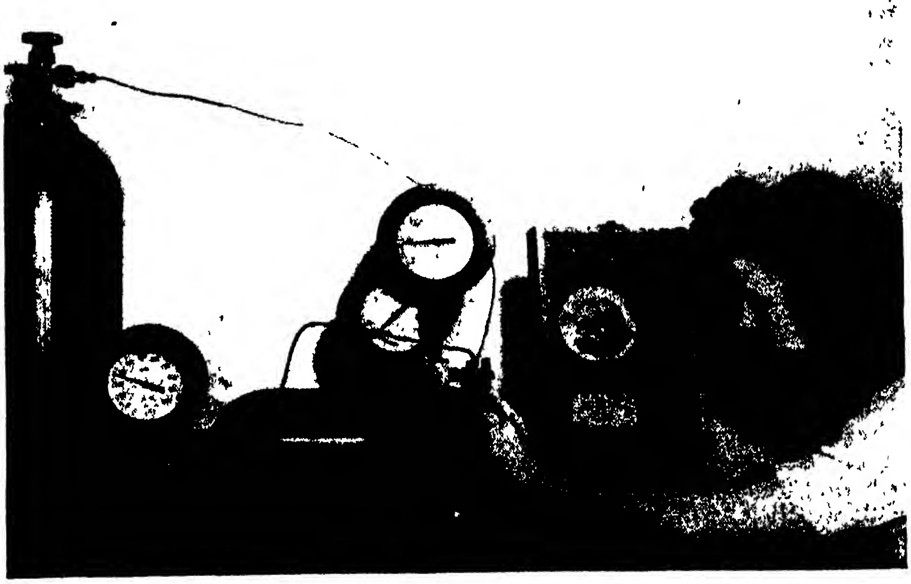
Conductance of Electrolytic Film Measures Water Vapor Content

A METHOD for measuring small amounts of water vapor in gases by means of an electrolytic film has been announced by the National Bureau of Standards. This procedure, which may also be extended to the determination of the moisture content of certain liquids and solids, depends essentially on the change in electrical resistance of an electrolytic film as it absorbs water vapor. Such a method has the advantages of speed, simplicity, high sensitivity and wide range. It is very flexible in operation and is readily adapted to numerous applications such as measuring the moisture-permeability of membranes, detecting minute concentrations of combustible gas in air or of oxygen in combustible gas, determining water vapor in aviators' oxygen or in liquid carbon dioxide, measuring the capacity of drying agents, determining the water content of organic liquids and solutions, and measuring the relative humidity in small or comparatively inaccessible spaces under rapidly changing conditions.

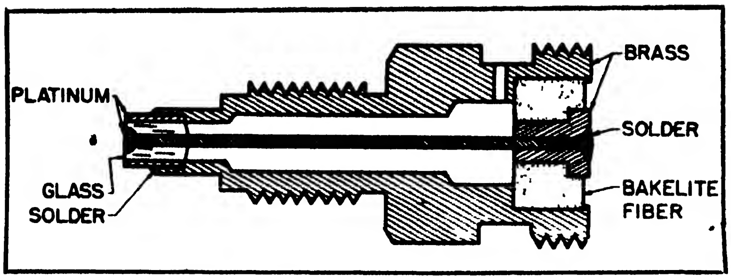
With this method a thin film of liquid—phosphoric acid, a solution of sulfuric acid or other electrolytic compounds in a gelatin or plastic binder—is spread over the surface of a solid insulator between metallic electrodes. The electrolyte tends to reach equilibrium with the water vapor in the surrounding gas and to form a solution, the electrical conductance of which is a measure of the concentration of water vapor in the gas. To utilize this phenomenon, some sensitive instrument for measuring or comparing electrical resistances and a means of calibrating the film by comparison with a gas of known moisture content are necessary. Because of polarization, alternating current must be used.

The apparatus developed by E. R. Weaver of the National Bureau of Standards, consists primarily of a "detector" (electrodes and the separating insulation on which the conducting film is spread, together with the necessary support), an indicating circuit involving an adjustable bridge with its power supply and amplifying device, and an indicating instrument such as a galvanometer or microammeter. Other necessary parts are a pressure-tight enclosure for the detector known as the "cell," a "saturator" for adding moisture to the reference gas, two pressure gages, a cylinder of compressed air or other gas, valves and connecting tubing.

The detector consists of concentric, glass-insulated platinum electrodes, mounted in a bushing which can be screwed into the cell. When either the gas to be tested or the reference gas is passed into the cell, the resistance of the electrolytic



Equipment for measuring moisture content by the National Bureau of Standards' method



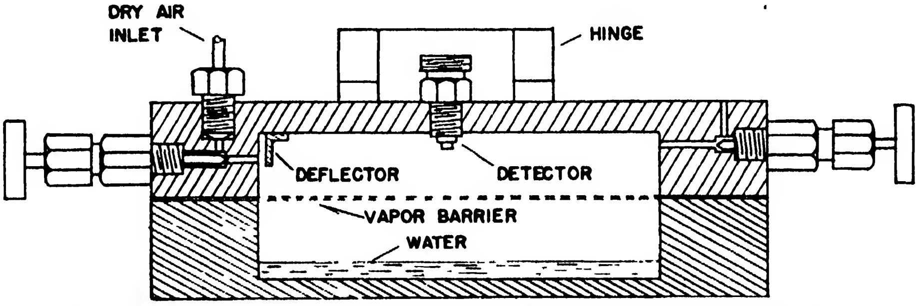
Detecting unit of the NBS water vapor detector. The electrolytic film is spread on the glass insulator between the platinum electrodes

film varies with the moisture in the gas, and this variation in conductance is indicated by the meter. The pressures of the two gases being compared are then adjusted until the meter readings are the same. In this procedure, the pressure gages actually serve as the measuring instruments; the meter is used only to show a null point. However, when moisture concentrations are changing rapidly, these changes are followed by means of current readings which are interpreted with the aid of a calibration curve.

The material most frequently used for the detecting film is phosphoric acid. The gas of known water content with which the unknown gas is compared is conveniently obtained by saturating air with water vapor at high pressure and expanding to any desired extent. For humidities too low to be conveniently matched in this manner, the moisture content, well below saturation, of a cylinder of compressed air is determined by comparison with air from the saturator, and the cylinder is subsequently used as a secondary standard.

It has been found practicable for an observer using this method to determine the compliance of oxygen with an exacting specification for dryness at the rate of 100 cylinders per hour. By use of secondary standards with some sacrifice of accuracy, it is possible to work with greater speed and convenience as well as at much lower concentrations of water vapor. Changes of less than one part per million of water in Freon from a refrigerating machine have been determined in this way without difficulty at intervals of one minute.

A simple and convenient auxiliary apparatus has been designed at the Bureau, by means of which this method may be used to determine extremely small concentrations of water in such liquids as ether or gasoline in a few minutes. Since the water concentration of a liquid of otherwise constant composition bears a definite relation at any given temperature to the humidity of air with which it is in equilibrium, the moisture concentration of a liquid may be quickly determined by measuring that of the air above it. A spring clip is applied to the detector so that a glass "test tube" with a small opening in the bottom may be quickly attached, making a snug but not air-tight fit with the detector plug and covering the sensitive film. When the detector with this attachment is lowered into a bottle of the liquid to be tested, the glass tube fills with liquid from well below the surface at a rate which forces air past the detector under slight pressure. The detector is lowered until the detecting film is only a few millimeters above the liquid surface. The resistance of the detector changes rapidly at first but soon becomes practically constant when the small volume of residual air becomes saturated. Since this volume is almost isolated from the surrounding atmosphere, which is itself almost in equilibrium with the liquid, there is very little disturbance by diffusion from the outside. Two or three minutes is usually sufficient to obtain a steady reading, and successive tests are reproducible.



Detector tests permeability of membranes. Membrane (vapor barrier) covers water container. Time for air over barrier to reach given humidity indicates permeability

The instrument appears to be applicable to almost any liquid. With those which produce alkaline vapors, however, an electrolyte other than phosphoric acid must be used on the detector. It is expected that this device may also prove useful in determining the moisture content of many substances—such as fats or cellulose derivatives—which are soluble in organic liquids.

The general applicability of the method to liquids suggests the possibility of determining the water in solids also. Candy can be dissolved in alcohol, butter or other grease in ether or carbon tetrachloride, and the water in the solutions quickly determined. A sample of soil, molding sand, or concrete-making material shaken with acetone may be expected to transfer its surface moisture to the liquid at once. Thus it should be possible to determine quickly the surface moisture of numerous powdered or granular solids by shaking a measured sample with a suitable liquid and, without removing the solid, submerging the attachment for testing liquids in the resulting solution.

EXPANSION FITTING

Liquid Nitrogen is Used To Shrink Metal Parts

High-purity liquid nitrogen, which can reduce the temperature of a piece of metal to 320 degrees below zero, F. in a few minutes, is now being used for expansion fitting.

Though it is generally easier to expand the outside member of an assembly than to shrink the inside part, the size or hardness of the members or the possibility of distortion may make shrinking advisable. Fits such as valve seat inserts, cylin-

Bucket is fitted with insulated well

der liners and bushings are almost impossible to make by expansion. The outer members are usually too large or complex, have finished external surfaces or have been heat-treated.

Liquid nitrogen, being inert, is recommended for such shrinking applications. Liquid oxygen has

A liquid nitrogen direct-immersion machine for the shrinking of small parts

been used for shrinking, especially during the war, but the properties of the oxygen-rich atmosphere create a potential hazard. Liquid air has also been used, but is not recommended since the nitrogen boils off first, leaving liquid oxygen.

For small-lot expansion-fitting operations, the most satisfactory arrangement is to use a stainless steel bucket having a well-insulated internal receptacle. The liquid nitrogen is placed in the inner container. The wooden cover is vented to avoid pressure build-up in the vessel. Tongs or a perforated ladle are used to dip small parts directly into the liquid.

For mass-production work, a machine is employed in which parts are fed either automatically or manually into the top and ejected after cooling as needed. As in nearly all such machines, the cold nitrogen vapor is used to pre-cool the part.

To supply the demands of large users, The Linde Air Products Company furnishes liquid nitrogen in 100-gallon mobile transfer tanks. These units are provided with heat exchanger coils enabling sufficient head pressure to be built for forcing the liquid nitrogen into the cold-treatment machine. For small users liquid nitrogen can be obtained in five-, 15-, 50- or 100-liter insulated containers.

Only a few precautions are necessary with this shrinking process. Care must be taken to assemble the parts quickly into final position. Parts warm up quite rapidly. Unless placed properly in position quickly the insert may become warmed sufficiently to bind.

Certain precautions for the operator should be observed. Good ventilation should be provided. Goggles are desirable and the operator should wear gloves for handling the cold parts. Great care must be taken in the handling of liquid nitrogen; if spilled on the hands, the material causes injuries similar to burns.

CHILLED BISMUTH DIES

Six to Ten Stampings Are Possible Between Chillings

A METAL that melts in hot water has been put to work by research engineers as a die material for making experimental parts. The soft metal—an alloy of bismuth, tin, and lead—ordinarily is too soft to stand the tremendous pressures imposed on dies. Ford Motor Company research engineers have overcome this obstacle by freezing the die in liquid nitrogen, which has a temperature of 320 degrees below zero, Fahrenheit.

This freezing action intensifies the hardness of the surface from a consistency comparable to dried putty to the far greater hardness of ordinary brass. From six to ten stampings can be secured between chillings in the frigid bath In the past experimental engineers have had to wait from six to eight weeks for small steel dies to be made. Soft metal dies are now produced and sample parts obtained in from 24 to 48 hours.

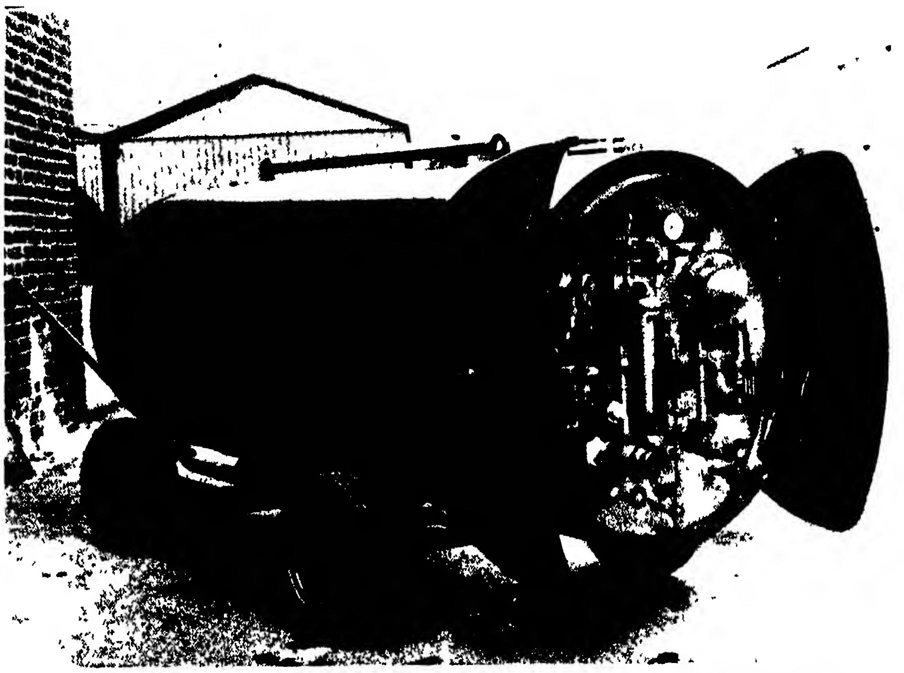
FINGER-TIP AIRCRAFT CONTROL

Small, Light-Weight Unit Developed For Navy

FINGER-TIP control of an airplane is possible through the use of a new small control station. This control station is normally mounted between the pilot and copilot and is part of a new all-electric lightweight automatic pilot which was recently developed by the General Electric Company's Marine and

Finger-tip control in operation

Aeronautics Engineering Division for the Navy Bureau of Aeronautics. A similar type of automatic pilot is also in development for the Air Forces.



This 100-gallon vacuum-insulated carrier is used to transport liquid nitrogen

New Products

SILENT MERCURY SWITCH

New Model Features Large Capacity And Long Service Life

HAVING a 10-ampere rating at 125 volts, a new silent mercury switch has been announced recently. A product of the General Electric Company's Appliance and Merchandise Department, Bridgeport, Connecticut, it replaces the five-ampere switch developed by that company. Doubling the interrupting capacity in the switch permits much wider application. While the five-ampere model could not control a load consuming more than 600 watts, the new model can be used in electrical installations of up to 1,200 watts. Operation of the switch is smooth and completely silent, and the unit is claimed to have an extremely long service life.

COTTON FIBER ANALYZER

Length and Uniformity of Fibers Are Accurately Determined

GUESSWORK is eliminated in determining length and uniformity of cotton fibers through the use of a new electronic instrument. This instrument, the Fibrograph, employs photo tubes to scan samples of parallel fibers and simultaneously traces a length-frequency curve. The geometrical properties of this curve indicate various average length intervals, variance and co-efficient of variation.

The Fibrograph, produced by the Fulton Sylphon Division, Robertshaw-Fulton Controls Company, Knoxville, Tennessee, operates on 110-volt, 60 cycle A.C. and is rated at 40 watts. However, units can be supplied on special order to operate other voltages.

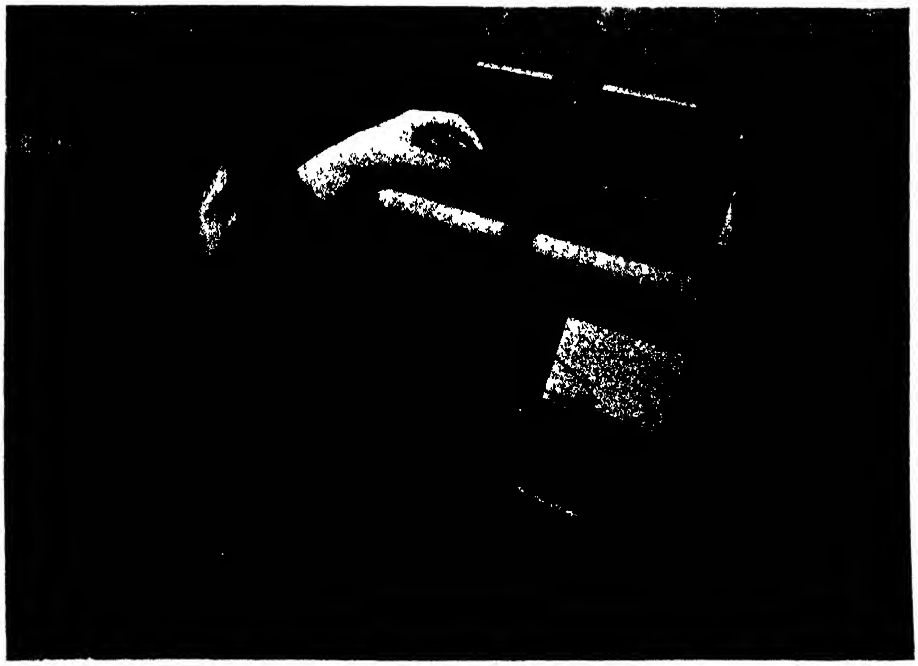


Photo tubes scan fibers and simultaneously trace a curve which reveals variations

RESISTANCE-TUNED OSCILLATOR

New Instrument Covers a Frequency Range of 10 to 10,000,000 Cycles

SAID TO be the first commercial instrument of its kind to provide audio measurement speed, ease and accuracy for readings at radio, video and audio frequencies, a new resistance-tuned oscillator covers a frequency range of from 10 cycles to 10 megacycles, in decade ranges. No zero setting is required, and minimum adjustments are necessary during operation. The highly stable instrument, designated Model 650A, by the manufacturer, the Hewlett-Packard Company, Palo Alto, California, operates virtually independently of line voltage and changes in tube characteristics. Output is flat within one decibel from 10 cycles to 10 megacycles. Voltage range is .00003 to three volts. Output impedance is 600 ohms, but a six-ohm impedance is also available through an output voltage divider, supplied with the instrument.

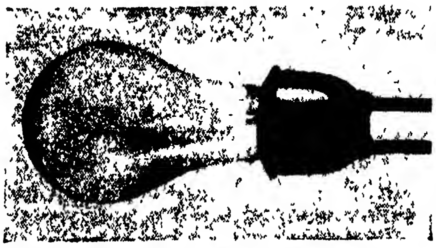
Other features of the new oscillator include a 94-inch scale length, a six to one micro-controlled vernier tuning drive and a complete vacuum tube voltmeter to monitor output in volts or decibels at the 600-ohm level. Continuously variable output voltage is obtained by means of an output attenuator of 50 decibels, variable in 10 decibel steps, and an amplitude control which adjusts the level to the monitoring vacuum tube voltmeter.

Operating entirely from a 115-volt A.C. power supply, the compact oscillator is provided either in relay rack or cabinet mounting. Panel size is 19 by 10½ inches and the instrument is 13 inches deep.

WATERPROOF SOCKET

Bulb and Receptacle Are Wholly Sealed in Rubber

THE UNUSUAL design and construction of a new all-purpose electric light socket make it completely waterproof, weatherproof and vaporproof. This



Sockets are available in standard colors

Neolite Weatherproof Socket "350," as it is designated, achieves its positive proofing against these elements through sealing with Neoprene. The phosphor spring bronze contact of the socket is embedded in Neoprene threads, while a moisture-tight lip of Neoprene seals the bulb, and the six-inch pigtail outlets are molded into the base. Absolutely no parts are exposed. The manufacturer, Neoline, Inc., Los Angeles, California, claims that with this sealing the Neolite may be submerged in water without fear of shock.

The unusual features of this socket make it well suited to outdoor decorative and utility lighting and for use wherever a lamp may be exposed to weather, oil or rough treatment. It is available in any standard color and in individual units or strung in sets of any length and any number of sockets, each socket being wired independently of the others.

DEPTH SOUNDER

All-Electronic Unit Measures From Zero to 600 Feet

A NEW all-electronic depth sounder for moderate-size commercial craft and yachts has been announced by Trident Products, Inc., Burbank, California. An

Complete sounder, excluding batteries, consists of two units — indicator (left) and transducer (right), connected by the flexible cable

extremely compact transducer employing a crystal sends a 50-kilocycle pulse and receives the echo from the ocean floor to determine depth. The transducer mounts inboard for easy servicing, and it requires a hole only three and one-half inches in diameter. To further simplify servicing, standard tubes and components have been used throughout. The complete installation, excluding batteries, consists of only two units. However, if remote indicators are desired, as many as five repeaters may be connected to the master indicator. Designated model DS-2, the instrument may be operated on six, 12, 32 or 110 volts, D.C. It draws only 30 watts. Depths from zero to 600 feet are continuously indicated on the large scale.

POLYACRYLIC ESTER

New Compound Has High Resistance To Heat, Ozone and Oils

CAPABLE of being compounded and vulcanized in a wide range of soft to hard compositions a new type American rubber is announced by the B. F. Goodrich Chemical Company, Cleveland, Ohio. The new product, to be known as Hycar P.A., is technically identified as a polyacrylic ester and is an elastomeric material resembling natural, pale crepe rubber in appearance. The vulcanized forms exhibit outstanding resistance to heat, oils, ultra-violet light, ozone and gas diffusion, and non-rigid compounds show extremely good flexing life. Compounding, molding, extruding, calendering and curing operations are readily accomplished with standard rubber processing equipment.

Available in both dry and latex forms, Hycar P.A. in the unvulcanized state is expected to find many applications as an adhesive and as a coating or impregnant for fabrics and papers Vulcanized products have shown outstanding performance as heat-resistant coatings on fabrics, heat and oil-resistant gaskets, hose, belting, oil seals and other mechanical applications. As an insulation coating on electric motor coils, and as a heat and oil-resistant jacket for wire, polyacrylic ester shows promise of extending the usefulness of electrical products.

Hycar P.A , now in semi-works production, was developed after many years of experimental work by the company's research laboratories on flexible compounds for high-temperature service. When tested under an electric iron at 400 degrees, F., for eight hours, the new material showed no apparent loss in properties, whereas older rubber compounds were completely deteriorated in a much shorter time. After 720 hours at 300 degrees, F., the polyacrylic ester shows a change in elongation of only 35 per cent in comparison with 75 per cent in seven hours for good rubber compounds. Ozone resistance is even more striking, 600 hours exposure showing less effect on the new material than six seconds exposure on rubber.

FIELD REPAIR UNIT

Tractor Power Take-Off Drives Combination Tool

EASILY attached to the spindle shaft of a tractor's power take-off, a convenient field repair unit has been developed by Sherman Products, Inc , Royal Oak, Michigan. This unit, called the Farmcrafter, can be adapted in the field as a drill press or a grinder, and it is equipped with a flexible shaft that accepts many standard attachments. Sharpening tools and repairing of farm equipment can be done on the spot, and no power source other than the tractor itself is required.

RADIATION EXPOSURE METER

Holding Instrument Up to Light Reveals Extent of Exposure

A POCKET dosimeter which provides an easily read indication of the amount of radiation to which the carrier has been exposed is announced by the Instrument Development Laboratories, Chicago, Illinois. This new instrument is designed for the safety of those working with X-rays or engaged in nuclear research. Designated model 8360, the dosimeter can be read merely by looking through its cupped eyepiece toward a light source. The amount of radiation to which the instrument and the bearer have been exposed is indicated in milliroentgens by an indicating line which is viewed against a magnified scale. The light-weight aluminum housing of the instrument does not appreciably distort the free-air reading. A molded conducting plastic cathode surrounds the ion chamber, and the anode of the instrument consists of a highly sensitive fused quartz fiber five microns in thickness.

SMALL ATTENUATORS

New Series of Bridged "T" Units Is Announced

A NEW series of small attenuators, said to be complete with all the quality features usually found in larger units, has been announced by the Shallcross Manufacturing Company, Collingdale, Pennsylvania. Measuring only 2⅛ inches in diameter, the new series of 20-step, bridged "T" units are designed to satisfy many important requirements for attenuators of highest quality which must meet space limitations.

The various attenuation characteristics available make these new units

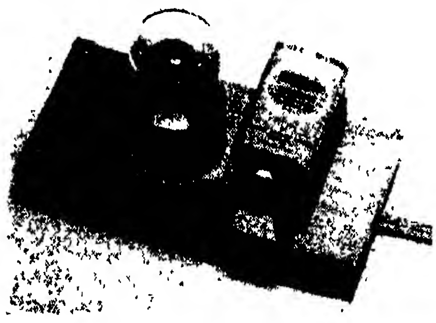
Field repair unit used as grinder. Tool is driven by the tractor's power take-off

suitable for use as mixer or master gain controls. The attenuation characteristic is essentially flat from 30 to 15,000 cycles. Attenuation in "off" position is said to be 100 decibels or better. All resistors used are non-inductively wound and sealed against moisture and shock. The back-of-panel depth is two inches for all units, or 2 5/16 inches when equipped with detent mechanism.

HEARING AID BATTERY CHARGER

Reducing Internal Resistance Extends Service Life

"B" BATTERIES for hearing aids can now be charged by a new battery charger. This device, developed by the



Battery in charging position

Selby Instrument Company, Long Beach, California, with the cooperation of the National Bureau of Standards and many leading battery manufacturers, decreases the internal resistance of the battery, thereby permitting fuller use of the potential battery life. The suggested procedure for using the charger is as follows. Two batteries are used—one is put in the hearing aid and the other is put on to charge. Each morning the batteries are rotated. This plan is said to result in an increase in the batteries' service life of up to 75 per cent. The unit operates on 110 volts.

LOW TEMPERATURE THERMOMETER

Measurements in Region of 10 K Are Accurately Made

BASED on a design by Dr. H. J Hoge of the National Bureau of Standards, a new platinum resistance thermometer

Usable at boiling point of helium

bulb is intended for calorimetric measurements at extremely low temperatures (10 K and higher). This thermometer has a platinum protecting tube 48 mm long and 5.6 mm outside diameter, and it can be easily mounted inside a calorimeter by casting in low-melting alloy. It is helium-filled and therefore is usable down to the boiling point of helium, approximately 5 K. Four-wire current and voltage leads are brought out through a glass seal. Nominal resistance at zero degree, C. is 25.5 ohms.

This instrument, a product of Leeds and Northrup, Philadelphia, Pennsylvania, can also be employed as a primary standard for resistance thermometer between −190 and +500 degrees, C., and can be supplied either with or without N.B.S. certificate for that range. When it is used with the type G-2 Mueller Bridge, temperature measurements can be made with an accuracy of ± 0.01 degree, C. in the calibrated range

REGISTRATION CONTROL

Sensitive Unit Checks Positioning Of Wrapper in Packaging Machine

A NEW registration control for use with packaging machines which employ web-fed wrappers has been developed recently by the Ripley Company, Inc., Torrington, Connecticut. The control consists of a scanner, and amplifier and a built-in relay unit. Connections are provided so that the cam on the feed of the packaging machine automatically corrects the position of the label whenever the web of the material gets out of register due to the slipping and stretching inherent in material of this type. The control is said to be so color sensitive that correction in the positioning of wrapping material is possible on such low color contrasts as red or brown on yellow, even though the marks be as thin as .015 inch.

The same method of scanning may be used when changing over from an opaque material to one that is translucent or transparent. The control can operate on either a light increase or on a light decrease, so the unit can scan a dark mark on a light background or a light mark on a dark background.

The control can operate at a rate of 750 units per minute with the correction on any sequence of registration marks. The equipment is compact and uses standard tubes and lamps to simplify maintenance. It operates on either 115 or 230 volts, 25 to 60 cycles.

IMPACT WRENCH

Powerful Air-Operated Tool Sets Bolts Rapidly

OPERATING without springs, gears, clutches or complicated devices, a new air-driven impact wrench sets nuts which would ordinarily require nut setters of far greater size and weight. An air motor of the rotary type fur-

Impact wrench takes bolts to ⅝ inch

nishes the speed and power for fast nut running in this unit. A built-in torque regulator is easily adjusted to the torque requirements of the individual job. The tool can also be run in reverse for use in disassembling operations. This wrench, recently announced by the Keller Tool Company of Grand Haven, Michigan, is designated Size 18-6 and will take bolts up to ⅝ inch Overall length is 8⅞ inches and the unit weighs only nine pounds.

ABRASIVE CUT-OFF MACHINE

Coolant Used to Extend Wheel Life And Give Finer Surface Finish

INTENDED chiefly for production-line work where fast cutting is necessary and yet tool or wheel life must be considered, a new abrasive cut-off machine has a coolant tank and pump for wet cutting. The use of coolant in this type of machine reduces cutting speed slightly, but it assures far better wheel life and leaves a surface finish free from burr and discoloration from burning. Wet cutting also leaves an unhardened surface, a fact of prime importance if further machining is to be done Toler-

Machine holds tolerance of 0.003 inch

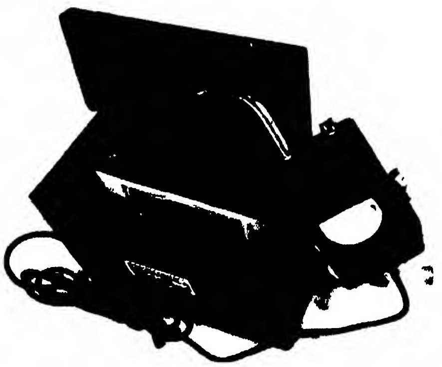
ances of 0.003 inch are said to be possible.

This machine, a product of the DoAll Company, Des Plaines, Illinois, is designed to provide extremely high wheel speeds for the fastest possible cutting. The wheel is fully enclosed in a heavy cast iron guard for safety A work vise operated by a foot pedal with sufficient leverage to hold work securely is standard equipment. Arbors are of one-inch chromevanadium steel mounted on pre-loaded ball bearings, sealed on the outside, and provided with adjustable take-up. Also included are stop gages for accurate cutting This machine, known as Model W, uses a 16-inch wheel powered by a 7½ horsepower motor, and has a capacity of three-inch tubing or two-inch solid bars.

AIR FLOW METER

Rate of Air Stream Is Accurately Measured by Hot Thermopile

Air velocities from five feet per minute to 6,000 feet per minute are accurately measured by a new air flow



Air meter requires no auxiliary equipment

meter. No other equipment such as stop watchs, hoses, leveling devices, manometers, orifices or pressure instruments is required with this air meter. It is a completely self-contained unit that operates on the hot thermopile principle. A noble metal thermopile is placed in the air stream to be measured. The hot junctions of the thermopile are heated by passing alternating currents through them. The cold junctions are prevented from becoming heated by lowering their resistance and by increasing the heat conductivity away from them. Therefore a D.C. thermal voltage is generated between the hot and cold junctions of the thermopile. The flow of air tends to bring the hot and cold junctions to the same temperature, thus decreasing the output from the thermopile. This output is a measure of the speed of the air flowing past the thermopile. An indicator or recorder operates from this difference voltage generated by the thermopile.

This instrument, known as the Air Meter, is produced by the Hastings Instrument Company, Inc. of Hampton, Virginia, and is said to be particularly free from errors due to temperature variations, radiation effects, and lead resistance. It can be operated either from a standard 110-volt, 60-cycle line or from a portable battery supply

HIGH-VOLTAGE SUPPLY

Output Is Said to Vary Less Than .01 Per Cent

A new zero to 5,000-volt reactance-regulated D.C. supply is announced by Instrument Development Laboratories, Chicago, Illinois. This unit, designated model 1090, is arranged for mounting in a standard relay rack. It features extremely good regulation. The output is said to vary less than 0.01 per cent with input variation between 90 and 130 volts. The output voltage is continuously variable between zero and 5,000 volts, positive or negative.

The unit contains only one vacuum tube, greatly simplifying maintenance and reducing the possible sources of failure. A large, easily read meter indicates the voltage output. This new supply is well suited for use with ion chambers, proportional and Geiger counters, and is especially well suited for use with the new high-voltage counters for soft beta radiation.

TEMPERATURE TRANSDUCER

Small Light-Weight Unit Features Accuracy and Quick Response

A new temperature transducer, only one inch in diameter, is designed for telemetering applications where space is at a premium. In this unit a temperature sensitive bi-metallic element encased in a small tube rotates a standard microtorque potentiometer Any change of the bi-metallic element due to the slightest change of temperature results in a large voltage output from the potentiometer. These voltage outputs are sufficiently large to be recorded by an oscilloscope, galvanometer recorder or a telemetering system.

Standard resistance for this instrument, a product of G. M Giannini and Company, Inc., of Los Angeles, California, is 5,000 ohms, but resistances are available from 100 to 20,000 ohms This temperature transducer has a range from —65 to +150 degrees, C. The unit is accurate to 1 per cent and has a sensitivity of one degree or less. Standard response time is two seconds for a five degree change in temperature.

MAGNETIC HAND LIFT

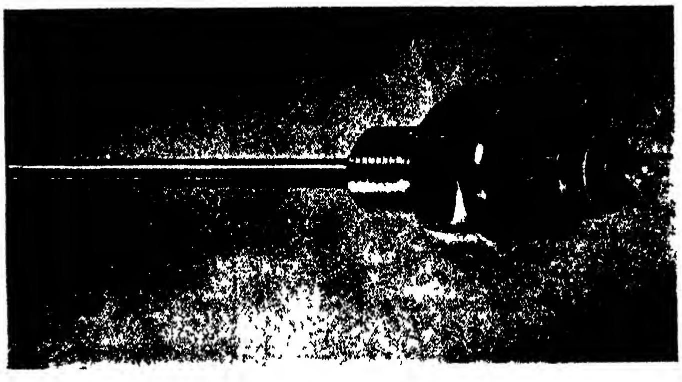
Two Alnico Magnets Aid Handling Of Small Steel Parts

Designed for the rapid handling of small parts of iron or of any magnetic alloy, a new light-weight magnetic

Hand lift will support up to 15 pounds

hand lift will support up to 15 pounds Heart of the device are the two four-inch Alnico magnets housed in the aluminum and stainless steel case. It requires no external power source and needs no maintenance. Known as the Multilift Model S Magnetic Separator, the unit is a product of the Multilift Manufacturing Company, Detroit, Michigan. In addition to its materials handling applications, the hand lift can also be used to draw steel parts from tumbling media, to remove heat-treated parts from carbon, to salvage steel parts or particles from aisles or assembly lines or for any operation where small steel parts are to be separated from non-magnetic pieces. The device measures three by five and one-half by eight inches and weighs only three and three-quarters pounds.

The transducer's output is sufficiently great to be recorded by an oscilloscope, a galvanometer or by a telemetering system. Temperature range is —65 to +150 degrees, C.



CURRENT BULLETIN BRIEFS

(The Editor will appreciate it if you will mention Scientific American when writing for any of the publications listed below.)

Cast Bronze Bearing Alloys. This is the first of a series of technical papers prepared to assist the engineer and designer in selecting the proper alloy for a given type of service. Complete engineering data on physical properties are included, and new material dealing with the hardness of cast bronzes is published for the first time. There is also a listing of characteristics and typical uses of different cast bronze bearing alloys. *The Bunting Brass and Bronze Company, 715 Spencer Street, Toledo 9, Ohio.—Gratis. 11 pages.*

Electromode Unit Heaters. Catalog EC-4. Describes in detail the complete line of Electromode Unit Heaters from 1500 watts to 60,000 watts. The book is fully illustrated with pictures of many installations heaters, controls and with wiring diagrams. It contains a Heating Analysis Sheet to assist in solving industrial heating problems. Includes a full page of illustrations of the complete line of Electromode portable and built-in-wall heaters. *Electromode Corporation, 45 Crouch Street, Rochester 3, New York.—Gratis. 15 pages.*

Wilson Tube Cleaners—Catalog No. 76. Covers the complete Wilson line of tube cleaners for use in refineries, power plants, marine boiler rooms, locomotives and chemical process plants. Described in detail is virtually every type of cutter-head, as well as brushes and air-, steam- and water-driven motors, electrically driven tube cleaning equipment and all accessories. All listings are organized for easy reference, and include application data as well as technical information, operating hints and other pertinent data. *Thomas C. Wilson, 21-11 44th Avenue, Long Island City 1, New York.—Gratis. 48 pages.*

Carboloy Die Engineering Manual (No. D-124) is a comprehensive presentation covering the design, fabrication, application and maintenance of carbide sheet metal dies. Designed specifically for the use of die manufacturers and large-scale users of carbide dies, the manual contains 36 pages of technical data, profusely illustrated treatments of "Designing, Assembling, and Finishing of Draw Dies", a similar treatment on Blanking Dies, a section on "Designing and Finishing of Punches" and an enumeration of the factors involved in ordering carbides for dies and punches, including tolerance specifications. Dimensional information as required for the manufacture of dies and punches of various sizes and types are given in tabular form in the various sections. *Carboloy Company, Incorporated, Detroit 32, Michigan.—Gratis. 36 pages.*

Wales Type "C" Hole Punching Units—Catalog C. The units illustrated and described in this new catalog are used primarily for punching rivet holes in sheets, angles and extrusions. Included are types "C," "CA," "E" and "EJ" units. Wales "C", "E" and "EJ" units are independent and self-contained with nothing attached to the press ram, providing rapid setup on press brake rails, and reducing press "down time" to an absolute minimum. The "CA" units are "C" units with built-in adjustable adapters which provide a front-to-back adjustment of 1½" maximum (¾" either side of center line). *Wales-Strippit Corporation, North Tonawanda, N. Y.—Gratis. 15 pages.*

Specialized Testing and Measuring Equipment Catalog. More than ninety modern equipments for specialized testing and measuring are presented in this book. Products are grouped under functional, or "use" headings, such as "Time, Speed, and Torque"—an arrangement which makes it easy to locate a product of specific interest. Covered in eleven sections are: Magnetic Equipment; Time, Speed, and Torque Measuring Equipment; Force, Strain, and Thickness Gages; Color, Light, and Spectro Equipment; Chemical Analysis Equipment; Resistance and Insulation Testing Equipment; Materials Testing Equipment; Fibration, Sound, and Balancing Equipment; Vacuum and Pressure Measuring Equipment; Electric Circuit Testing Equipment; Miscellaneous Equipment. *General Electric Company, Apparatus Department, Schenectady 5, New York. —Gratis. 43 pages.*

Link-Belt Bulk-Flo. This handsomely printed and illustrated bulletin describes Bulk-Flo—a combination elevator, conveyor and feeder for the mechanical handling of a great variety of bulk flowable granular, crushed, ground or pulverized materials of a non-abrasive, non-corrosive nature. Made in Separated-Run and Combined-Run designs, numerous arrangements are possible of Bulk-Flo Conveyors because of their interchangeable standardized casing elements. Suitable for the majority of installations are three main machines consisting of horizontal, L-path and loop-loading arrangements. Fully explained in the bulletin are the Separated-Run design; the Combined-Run design; Design Features; Installations. Engineering Data are comprehensively presented and documented. *Link-Belt Company, 2680 Woolworth Building, New York, New York.—Gratis. 47 pages.*

Patents and How to Obtain Them—No. 64—1947 edition by B. M. Aldrich, Associate Professor of Mechanical Engineering at Oklahoma A & M College, may be had for the asking by writing the author or the *Engineering Experiment Station, Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma.—23 pages.*

Books

THE BOOK DEPARTMENT of Scientific American is conducted, with the co-operation of the Editors, to make available for you a comprehensive book service. Each month the Editors select and review in these columns new books in a wide range of scientific and technical fields. In addition, they are ready at all times to advise you regarding the best available books on any subject. You are invited to use this service freely. Tell our Book Department what kind of books you want and you will be furnished with the names of available books, including prices. When inquiring about books, please be specific; remember that we can be of the greatest help only when you tell us just what you are looking for. Books listed in these columns may be ordered from our Book Department. Add 25 cents per book for mailing outside U. S. All remittances are to be made in U. S. funds. Prices given are subject to change without notice.

PRINCIPLES OF JET PROPULSION

By M. J. Zucrow

THE AUTHOR, Professor of Gas Turbines and Jet Propulsion at Purdue University, presents a discussion of the fundamental theory pertinent to an intelligent understanding of jet-propulsion engines and gas-turbine power plants. Workings of the continuous combustion gas turbine, the three basic types of air compressors, the axial-flow turbine, the combustion chamber, high-temperature metallurgy, the turbojet engine and the rocket are all given excellent coverage. This book contains a wealth of material for the serious student. But if it is a popularization of the subject you want, this is not your book. (563 pages, 6 by 9¼ inches, illustrated with charts and line drawings.)—$6.60 postpaid.—*N.H.U.*

MANUAL OF ASTRONOMY

By Shaw and Boothroyd

FROM THESE 47 practical exercises amateur astronomers would derive far better systematic knowledge of working astronomy than from reading textbooks alone. Lone wolves probably would bog down for lack of fellow inspiration but groups working in unison would provide this necessary motivation. Questions asked are to be answered in writing in spaces in the manual, often on graph paper bound with it. Coverage: stars; planets; sun; moon; time and position; meteors; clusters; instruments; spectra; nebulae; navigation. Manual is used in teaching elementary astronomy at Cornell and elsewhere. This is *not* a textbook but an accessory to one. (294 pages, 8½ by 11 inches, well illustrated.)—$3.10 postpaid.—*A.G.I.*

MATRIX AND TENSOR CALCULUS

By Aristotle D. Michal

MATRIX calculus is a purely analytic and algebraic subject. Tensor calculus is geometric, handling the transformation of coördinates and other geometric concepts. Matrix calculus helps solve problems of mechanical systems which have more than one degree of freedom. Tensor calculus helps solve the more intricate problems of the mechanics of fluids, and plastic and elastic media. Together they are powerful tools for the designers of airplanes, to whom Professor Michal (of California Institute of Technology) is a dependable and handy counsellor. (132 pages, 6 by 9¼ inches, illustrated.)—$3.10 postpaid.—*M.W.*

LIFE AND TIMES OF TYCHO BRAHE

By John Allyne Gade

RAPIDLY moving, thoroughly readable, lively entertaining account of the life of the most famous scientist of his day—astronomer (astrologer, alchemist also), the second link in the great chain Copernicus, Brahe, Kepler, Galilei, Newton. On his islet near Copenhagen he performed marvels of exact astronomical routine position observation without telescopes, none then existing. He was egocentric, difficult, imprudently combative, probably a paranoid. It is all here, good and not so good. (209 pages, 6 by 9 inches, 26 illustrations.)—$3.60 postpaid.—*A.G.I.*

FLEDGELINGS

By F. Regis Noel

THIS is a remarkably interesting collection of historical monographs written by outstanding authorities, thus: Nils H. Randers-Pehrson, formerly of the Division of Aeronautics in the Library of Congress, writes on Aeronautics in the District of Columbia and goes back as far as 1784, when an attempt was made to fly a Montgolfier type balloon. Mr. Randers-Pehrson deals with early balloon exploit and has first-hand information on Lengley's work.

Dr. Albert F. Zahm, who now holds the Guggenheim Chair of Aeronautics, Library of Congress, begins his article with the following striking paragraph:

"Of the nineteenth-century contributions to aviation art three are especially noteworthy: (1) invention of the airplane, (2) addition of three-torque control, (3) first man-flights with ample power. In 1842 W. S. Henson patented the airplane with all organs essential to pioneer flight. In 1884 A. Goupil portrayed it nicely streamlined and endowed with aileron controls. Both forms were monoplanes, well delineated and discussed but never actually constructed. In the ensuing nineties C. Ader developed successively three monoplanes with aerodynamic control and abundant steam power. Each of these he piloted in brief flight witnessed by assistants. Thus before 1900 the airplane was invented, refined, publicized, built and test-flown."

Other contributors in this historical review include Mrs. Gilbert H. Grosvenor, daughter of Alexander Graham Bell; John C. Proctor, Editor-in-chief of "Washington Past and Present"; and F. Regis Noel, President of the Columbia Historical Society and former President of the Bar Association of the District of Columbia.

The whole series of pamphlets and papers constitute remarkable historic records. As the discovery of aviation becomes more important, all history records should be made as complete as possible. (79 pages).—$1.60 postpaid.—*A.K.*

ELEMENTS OF RADIO Second Edition

By Abraham and William Marcus

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By J. M. DallaValle

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THE AMERICAN ANNUAL OF PHOTOGRAPHY — Volume 62

Edited by Fraprie and Jordan

WIDELY KNOWN annual regularly purchased by many amateur photographers. Articles on 16 prints shown; exploded views; art of exposure; success in color, early photographs; sensitometry; film; 63 pages of the year's pictorial illustrations; who's who in pictorial photography; list of amateur photographic organizations by states. (216 text pages, 7¼ by 9¾ inches, heavily illustrated.) —Cloth, $3 10 postpaid. Paper, $2 10 postpaid. —*A G I.*

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By Worthing and Halliday

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By G. A. Hawkins

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well-balanced treatment of the subject of engineering thermodynamics for use in a two-semester undergraduate course of three credit hours per semester." Yet for more inquisitive students he provides a short list of selected references at the ends of several chapters. For the less inquisitive he suggests omitting five out of his 21 chapters. And, reflecting the despair of many an author, he hopes "that typographical and numerical errors have been reduced to a minimum. I expect, however, to receive information proving that this hope is ill-founded." What might be called a kind of "sequential analysis" search for such errors reveals none. (436 pages, 5½ by 8¾ inches, illustrations.)—$4.60 postpaid.—*M.W.*

ORGANIZING SCIENTIFIC RESEARCH FOR WAR

By Irvin Stewart

Another of the "Science in World War II" series, this one being about the administrative history of the OSRD and written by its deputy director who is president of West Virginia University. Coverage: From the beginnings through to demobilization of ORSD. If you found it a bit hard to focus the overall picture out of the fogs of wartime OSRD, this can be your focusing screw. It is a straight, factual account which names scores of names. (358 pages, 5½ by 8½ inches, unillustrated.)—$5.10 postpaid.—*A.G.I.*

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By T. H. James and George C. Higgins

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TECHNIQUES OF OBSERVING THE WEATHER

By B. C. Haynes

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WHAT'S A "TN"?

Not Derogatory, It's A Compliment

Just as amateur users and collectors of firearms show vigorous enthusiasm over their hobby and call themselves "gun cranks," so do many of the equally ardent followers of the amateur telescope-making hobby call themselves TNs, or telescope nuts, a term originally coined on the spur of an amusing moment by the humorist spouse of the hobby's patron saint, Russell W. Porter. The more staid, dignified minority of amateur telescope makers, perhaps suspicious of the underlying connotation of this equivocal term, do go so far as to call themselves ATMs, meaning amateur telescope makers, but an unregenerate TN wag named Pat Driscoll claims this means amateur telescope maniacs. It is good psychosomatic medicine to have something to be slightly crazy about, anyway.

The reader shown in the accompanying photograph qualifies both as ATM and TN by making four telescopes. "I think," he writes, "that I can lay claim to a maximum amount of variety in types of telescopes I have built.

A typical "TN"

"My first, the one shown at extreme left, was 8 inches in aperture with concave glass mirrors and was given a mounting of two-inch pipe fittings.

"To carry this rather bulky instrument from Philadelphia, where it was made, to Maine, where I summer, proved too much of a problem so I built the four-inch portable reflector shown on a tripod to right of the first. Loss of magnification was made up for by the advantage of portability; the weight was just 14 pounds.

"Having by now mastered more of the technique of making optical surfaces I next built the 2¾-inch refracting telescope shown third from the left, and I gave it the terrestrial (erecting) eyepiece shown at right angles to the tube. This one is not so powerful as the others but making it was a lot of fun.

"My latest venture was the short, stubby 'richest-field' reflector (shown in my arms) for observing broad fields of stars."

Few who make one telescope stop at one telescope. The mania leads in two directions: (1) larger telescopes (2) different types. First telescopes usually cost the spare time of three months; second jobs a month; third jobs a week and after that they almost make themselves.

Telescoptics

A Monthly Department for the Amateur Telescope Maker

Conducted by ALBERT G. INGALLS

Editor of the Scientific American books "Amateur Telescope Making" and "Amateur Telescope Making—Advanced"

PORTLAND, Oregon, contains an energetic group of enthusiasts, the "Portland Amateur Telescope Makers and Observers," of which Howard Thomas, 2242 N.W. Hoyt Street, is the president. A 20½" Cassegrainian reflector (Figures 1, 2, 3,) designed by Col. Alan E. Gee (see "A.T.M.A." page 320) and built with the help of A. E McIntosh, both of that group, is an ambitious job such as workers who have made half a dozen smaller telescopes may aspire to tackle as a climax.

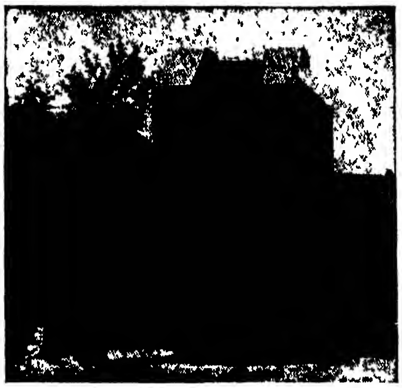


Figure 1: Portland's observatory

The massive, chunky polar axis unit (Figure 2) consists of a rectangular yoke like the one on the 200" telescope, at its bottom a central stub shaft, at its top a "horseshoe" permitting the telescope to view stars fully down in line with the axis, a design feature originated by Porter. The sides and bottom of the yoke are welded of 6" by 8" I-(C.B.) beams and the horseshoe is full 1" steel plate. It rolls on ball-bearing trunnions on a concrete pier. The stub shaft at bottom is 3½" in diameter and is carried in self-alining steel balls. It carries a 20" bronze worm drive wheel with self-computing slip ring (Figure 3).

Figure 2: The 20½" telescope

The 20½" mirror is one made in 1936 by C. R. Tinsley and is a tenth-scale honeycombed Pyrex 716 replica of the 200" mirror. It has a 33-rib support system designed by Gee and built by McIntosh. Its 80" focal length gives focal ratio f/4 which a 6" convex secondary mirror extends to f/12 or a 4½" secondary mirror to a seldom used f/20.

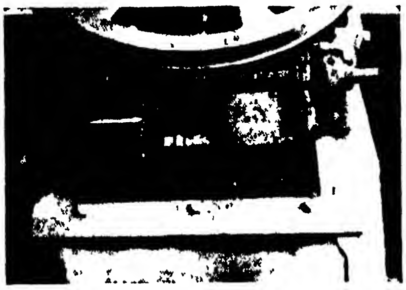


Figure 3: The drive and worm

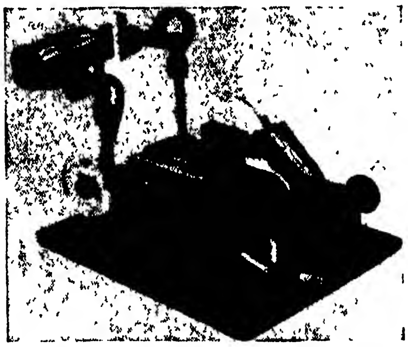


Figure 4: Maher-Thomas tester

For the famous Foucault knife-edge test, which reveals at a look irregularities as small as a millionth of an inch on a telescope mirror, a dulled razor blade mounted vertically on a weighted stick is sufficient—not alone sufficient but many old hands say just as good as something fancy. Nevertheless an apparatus like the one in Figures 4 and 5, built by T. P. Maher and H. D. Thomas of the Portland organization,

has points. Anyway, it is fun to build one

The levitated drawing (Figure 5) reveals parts:

A: Knife-edge and lamp support.

B: Lucite (2½") hand wheel, block, eccentric bushing Assembly held in place by 8-32 machine screws through to base plate of apparatus.

C: Way and slide of ⅛" brass. Pinion rack sweated to it.

D: Brass shims (0.015") for bearing plates to prevent slide from riding on Lucite scale.

E: Cross feed slide and way.

F: Bearing plate (⅛") for *E*.

G: Maple, ⅞" × 1½" × 4".

H: Base plate, ⅜" × 6" × 8" boiler plate, purposely heavy. Has three rivets beneath for stable support.

I. Prism (1¼") mounted on knife-

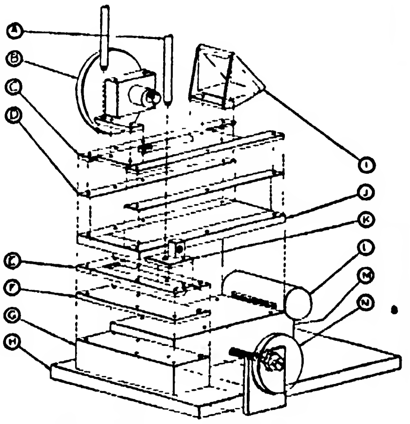


Figure 5: Parts for Figure 4

edge slide to permit reading the Barr's scale ("A T M.A.," page 20) from a convenient testing position.

J: Barr's scale ruled on Lucite sheet, 2½" × 6". Black photographic tape acts as a light stop on three sides of this block.

K: Cross feed nut.

L. Lamp to illuminate Barr's scale through edge of Lucite block. Scale shows as bright line on black background, easy to read in darkened room. Use 6-8 volt radio pilot lamp.

M. Maple, 1⅛" × 2½" × 4⅞", doweled and glued to *G*.

N: Cross feed screw and Lucite hand wheel. This could be graduated and illuminated in the same manner as the Barr's scale.

The pinhole illuminator is a flashlight bulb in a brass mounting. A condensing lens, prism, and ground glass are in the train to pinhole. Spring clips on knife-edge holder and lamp permit quick change from pinhole to slit, knife-edge to Ronchi grating. Support clamps on lamp and knife-edge stand are common ¼" oil line compression Ts. The Ts are drilled out to pass the ¼" rod, and compression ferrule split so it grips rod on slight twist of nut. This feature has worked very satisfactorily, affording easy raising, lowering, and minor adjustments.

Door-bell transformer (Figure 4) supplies power for all lighting.

Instrument weighs eight pounds.

The same Portland group devised a

kind of Robinson Crusoe method of ruling divided circles without lathe or dividing head. A 50' steel tape was laid out in a square 100" on a side. To obtain square corners, and to avoid injuring the tape, a loop of excess tape was allowed at each corner, and each side of the square was stretched separately with strings tied on. The square was squared within 1/16" by measuring the diagonals. Disk to be ruled was set at exact center. On it was set a 5-power telescope with cross-hairs at points based on tangents of desired angles.

An engraver made of drill rod running against a guide made the marks. Spacings down to five minutes of arc were obtainable without introducing fictitious accuracy. This method is also independent of tape expansion.

The circles made look like dividing engine jobs.

INTEREST in refractors steadily increases but crown and flint blanks have been almost unobtainable since the war. Check over the known sources. B. and L. hasn't acted interested in sales to amateurs. Corning now makes some 15 types of optical glass and will sell—if you need half a ton. A West Coast supply has petered out. A year's effort by this department to arrange a supply with the English Chance Brothers came to naught. The French Parra-Mantois glass is apparently unavailable and the German plant at Jena was lugged home by the Russians. "What is left," writes one amateur (G.D.H.), "for the poor Joe Doke who wants to grind a telescope lens?"

The pointed comment just quoted was shown, last August, to the Col. Alan Gee mentioned above in connection with the Portland group and who had just moved to Rochester, N. Y., (129 Seminole Way) sent there by the Army to study advanced optical design at the University of Rochester. He promptly went to Bausch and Lomb, talked with their Manager of Specialty Sales, J. F. Brandt, and on behalf of his fellow amateurs (once an amateur always an amateur), completed arrangements by which the amateur now may get his glass.

Available from Brandt after April 1 will be, not a wide selection of crowns and flints but the following as a postwar starter: A 3½" pair, BSC-2 (1.5170,64.5) and DF-2 (1.6170,36.6) $11 postpaid; optional: tool blank of C-50 at $3.25. Also 4½" same glasses, $21.75, postpaid. Tool blank, optional, $4.25.

"The disks," Brandt writes, "will be made of our regular instrument glass such as we use in all our instruments and due regard will be given to the quality demanded for astronomical objectives of this size. We have set the price on these and are putting in this stock entirely with the idea of being of some service to the amateur telescope maker. We are largely guided by the fact that you have felt that there should be more refractors made by amateurs and are making commercially available a stock of glass to back you up. We are sorry it has taken so long to accomplish anything, but

you can well imagine that under today's circumstances many a problem like this gets kicked around a bit before a chance comes to do something about it. The sets will be in stock April 1 at the latest. The sales will be made direct from the factory only, and not through dealers since this is entirely a service proposition."

Just why this particular glass? It was suggested by Col. Gee. "These," he writes, "are the two for which Baker gives all the curves for four different types of objectives in Dimitroff and Baker, 'Telescopes and Accessories', pages 28-29." Asked about these objectives, Dr. Baker indicated that nothing had been said in "Telescopes and Accessories" of their excellence; they were merely inserted poker-face.

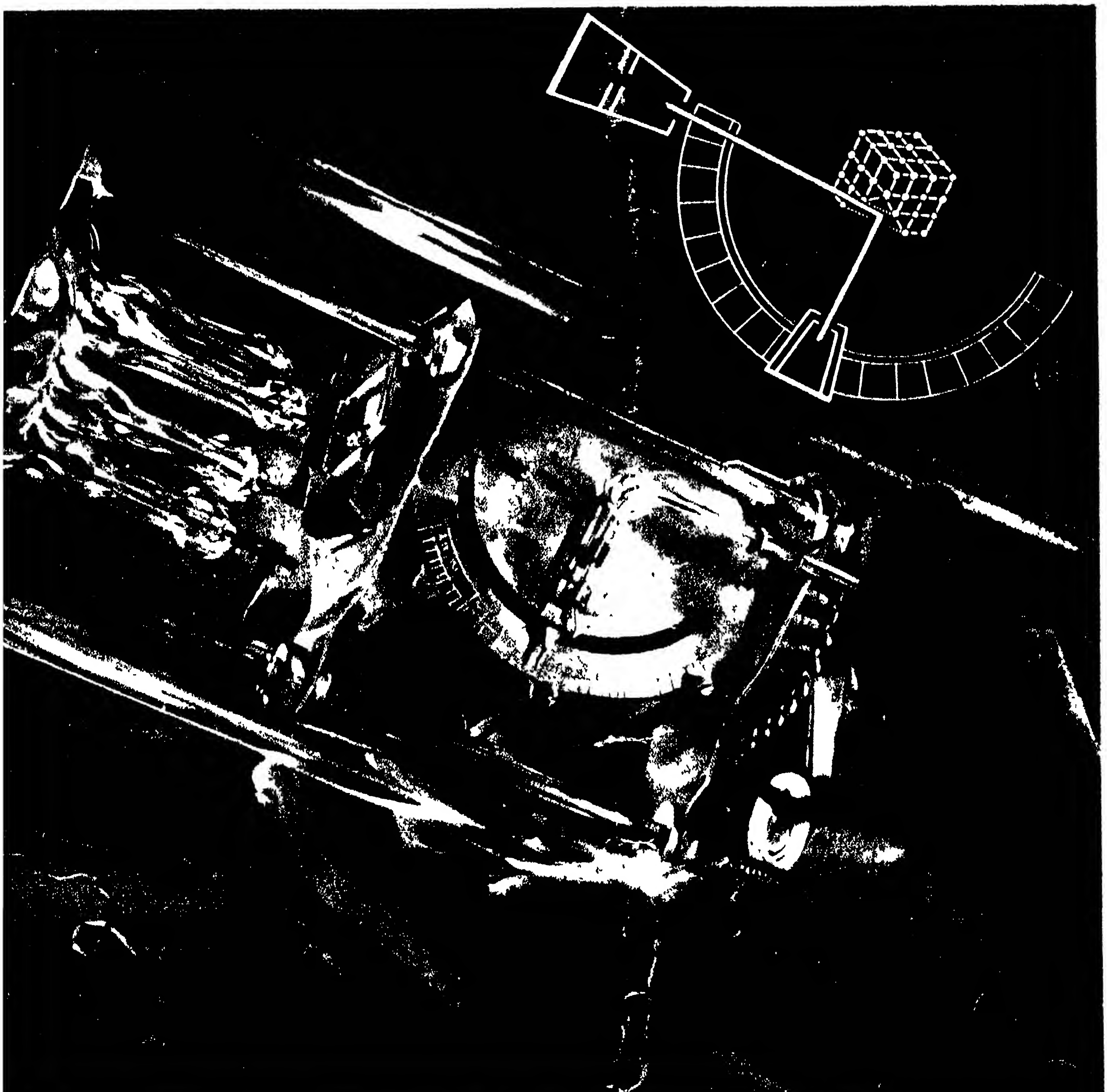
"I had my tongue in my cheek, back in '44," he writes, "when I put the refractor designs in the book on telescopes with Dimitroff. For the separated doublet offers a correction within a very small fraction of the Rayleigh limit, both for spherical aberration and coma, and is as good as can be done short of special glasses not available to amateurs in general. I wonder how many amateurs took the design seriously. We made up a 6" of the kind during the war and had excellent luck. The design can be carried even to f/3.5 before departing from the Rayleigh limit."

Gee's selection of B. and L's Brandt's glasses for Baker's objectives looks like a happy inspiration. Another worker's comment is: "Of course, the glasses will not exactly match the general catalog index except in rare instances but will vary in the fourth decimal place. But this, while objectionable in the very finest possible objectives, can largely be accommodated by varying the separation of the two components. A really top-class design calls for trigonometrical ray tracing to eliminate some of the aberrations, as only spherical aberration can be eliminated by local figuring. Not 'any old design' calculated from the general formulas for curves with algebra will give highly satisfactory results."

NOW FOR some long overdue tactlessness. Let's be rough and get it over with. For many years large optical firms have received SOS letters from amateur telescope makers. No doubt the following is exaggerated. "I am making a telescope using your goods and my troubles this week are a turned edge, zones, scratches, pits. The enclosed beautiful drawing shows my shadows. If it weren't for the edge, the zones, the scratches, and the pits, would this be a paraboloid or must I go back to grinding? If so, to what stage? Answer soon by air. P. S.: Please include all you know about abrasives, pitch, strokes, pressure, and testing."

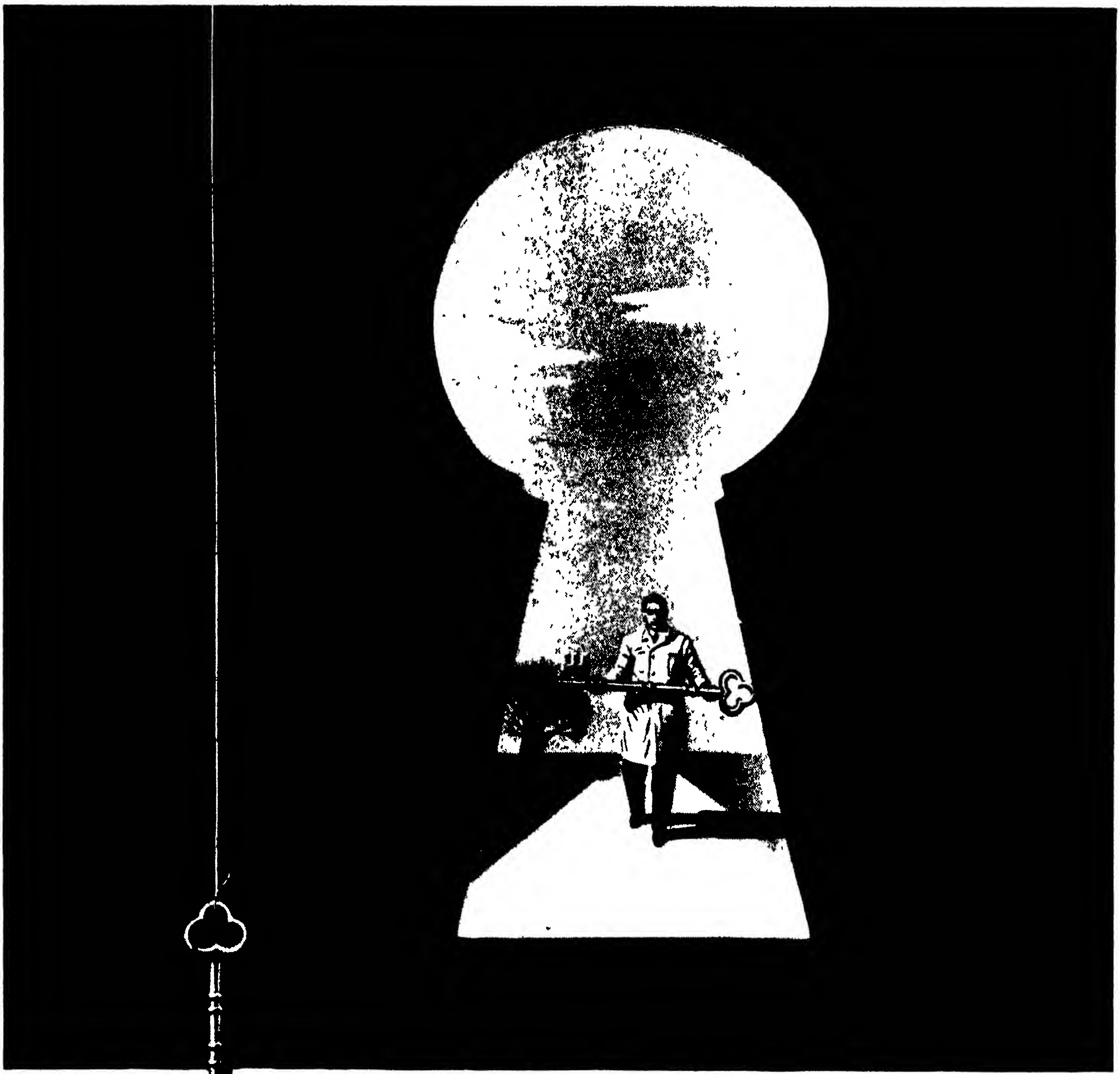
Men in these firms like amateurs, envy their fun, want to be agreeable, but aren't altogether free. Answering these Mr. Anthony letters takes long hours, costs money. Let's send them to Dorothy Dix or others and not spoil our "in" with the big boys.

SCIENTIFIC AMERICAN



THE ELECTRON: PARTICLE AND WAVE (PAGE 50) FIFTY CENTS

May 1948



LETTERS

Sirs:

Two years ago you described to me your plan for the founding of *The Sciences*, a new magazine which was to cover all of science for the intelligent layman. Now, I understand, you have combined your plan for *The Sciences* with the acquisition of the venerable *Scientific American.* I hope you have not taken the change of title too literally. Science is not American—it transcends nations. But the *Scientific American* is an established name, doubtless chosen for good reasons. What will be between your covers is the important question.

Your original prospectus asserted that the new *Scientific American* would be designed to fill a gap in American journalism. I, for one, have been acutely aware of this gap.

Technical journals for technical readers abound and are, mostly, excellent. Popular articles, even entire magazines, on science and technology for mass readers have also grown in abundance and, more slowly, in excellence. Twenty years ago, those of us in science who were concerned with the problem cried for almost any science coverage that would give the citizen (who pays the bills and should enjoy the party) even the simplest undistorted information. Today, while plenty remains to be done, trained science writers, working with the media for reaching men by the millions, do present the findings of science and some of their underlying significance, and often do it well, sometimes superbly. But even if this job of mass communication were done to perfection, certain inexorable limitations would exist.

Science writing addressed to the citizen must not assume general erudition, a background of understanding, an intelligent interest that he does not possess. College science presented to grade-school pupils will alienate, not educate, them. The bulk of adult Americans, even those of entirely adequate intelligence, is not today beyond a most elementary acquaintance with science. We must hope that better teaching in schools, that adult-education efforts, that the presentation of simple but genuine science in print and by exhibits and over the airways, will slowly raise this level.

What then of the tens or hundreds of thousands prepared and eager to keep abreast of science at, say, a college level? Each scientist is an advanced layman outside his limited area of expertness. So are professional men of all callings. These men need something between the particular technical journals and the generalized mass magazines. I hope the *Scientific American* will meet this need.

I am concerned that the need be met, not so that some magazine or other be a

yesterday we have received your recent "CARE" package. Once more the unpacking of these very useful foods has been a joy
Par cette lettre je vous remercie d'un nouveau colis que vous avez e la bonté de m'envoyer
All the wonderful foods in your CARE package are still scarce here. It is impossible for you to imagine how des-
My greatest thanks for the parcel you have sent to me with CARE.
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(signature of sender) (Date)
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success, nor that some intellectuals be satisfied, but that civilization be aided. For this group of men, largely if not wholly self-selected by talent and enterprise, dominates the thinking of the larger citizenry. The lawyer, the doctor, the engineer, the business executive, hardly less than the educator, the minister, the publicist, the artist, is a maker of the minds of men; it is vital that he help make them well. No more important ingredient can be included in the mix than that habit of rational analysis and calculated testing and objective evaluation which is epitomized in the scientific method. If I may quote a few words I wrote a year ago:

"If we think of science as an exciting sport, as indeed it is, then the final score of each game is certainly for the public. So also is the inning-by-inning progress, provided it is clearly recognized by all as just a progress report and provided the reporter has some official or semi-official authority for his statements. Still better, if the public is taught some of the rules of the game, it can follow with excitement a play-by-play account. It must never be placed in the role of umpire. Also, it must learn to respect the expertness of the players. A democracy that does not respect expertness in the intellectual area, as it does in the sports arena, is bound for extinction in an age of technology.

"Let me sum up. For a healthy democracy the following circular relations should hold: The public should be kept informed of the authoritative advances of science and, even more, should be instructed in the manner in which science achieves them. The public must be made aware of the dignity of expertness and the compulsion of facts. Only so can the state, and all states, act rationally in this era of great sociological interdependence and tremendous physical power. Only so will science receive the financial support and dignified position it must have for the good of the whole. Only so will science flourish and serve. Those who work with the mass media of communication must insist on ever better standards of reliability and significance in what they communicate—standards which guarantee the discharge of a public duty as well as accumulation of a private gain. Only so will they be allowed long to continue as private enterprises. Only so can the public learn what it must know to function as a democracy."

So if the new *Scientific American* has indeed chosen to convey science in an accurate and lucid manner to the intelligent layman, it has chosen a momentous and difficult task. It is earnestly to be hoped that it will succeed.

R. W. GERARD

Department of Physiology
University of Chicago
Chicago, Illinois

50 AND 100 YEARS AGO

MAY 1898. "It is interesting to recall that just thirty-five years ago—on March 4, 1863—the National Academy of Sciences was created. This year, as in years gone by, the academy met in Washington. A programme of twenty papers was presented at this meeting. Of these, three were by Alexander Agassiz, the director of the Museum of Comparative Zoology, in Cambridge. Dr. Agassiz has spent considerable time during the last year studying the coral reefs of the Pacific."

"The brilliant operations of the American fleet in Manila Bay have served to emphasize several well established principles of naval warfare, the truth of which has been recognized through many centuries of struggle for the mastery of the seas. We believe it was Napoleon who said that Providence was on the side of big battalions. That may be true on land, but the history of sea fights without number has taught us that Providence is on the side of forethought, good judgment, discipline, dash, well-timed audacity and above all straight shooting."

"The 'Windward,' the Arctic exploring ship which was presented to Lieut. R. E. Peary, U.S.N., the Arctic explorer, by Mr. Albert Charles Harmsworth, owner of The London Daily Mail, arrived at New York, May 11, after a rough passage of fifty-two days. The 'Windward' is notable as being the vessel which took Nansen and Johansen from Franz-Josef Land to Norway. Lieut. Peary's plan has also been outlined. He will leave in July for the North, and as the expedition may be gone several years, the 'Windward' will carry stores from New York at intervals of a year or two."

"In the middle of June the great star Arcturus is overhead. Even for those who know and care but little about astronomy it is worth while to look carefully at Arcturus, because Arcturus is the very mightiest sun that the heavens are known to contain. Its distance is about a thousand millions of millions of miles, or more than ten million times the distance of our own sun. Since the intensity of light decreases as the square of the distance increases, it is easy to show that if we were as near to Arcturus as we are to the sun, the earth would be vaporized by the blast of unimaginable heat which would smite it, for Arcturus must exceed the sun in light and heat giving power in the ratio of six thousand to one!"

"At a meeting of the New York Academy of Sciences, Mr. E. L. Thorndike, of Columbia University, gave an account of a long series of interesting experiments on comparative psychology. These experiments were made upon cats, chickens, dogs, monkeys and other animals, and were supplemented by the experience of professional animal trainers. Cats were placed in boxes with doors so arranged that they could be opened from the inside in various ways, in one set of experiments by pressing a latch, in another by pulling a cord, by pulling a hook attached to a cord, or by turning a button. Curves were given showing the rate at which kittens learned the various tricks, the time taken to get out becoming gradually shorter."

"Mr. William Doherty, an American ornithologist and entomologist of reputation, has just returned to this country from the Philippine Islands, via Hong-Kong and San Francisco. His latest distinction was in successfully passing the Spanish customs officers at Manila with the complete plans of the city, the harbor, fortifications and minute details of the armament. It was a dangerous proceeding, but Mr. Doherty carried it out successfully. The plans and drawings were concealed in a newly laundried shirt which was folded, pinned and banded in the usual style and put with other clothing in his trunk. He arrived in Hong-Kong early in April and at once delivered these most important papers to Commodore Dewey on the 'Olympia'."

MAY 1848. "We thought that the revolution in France would have unsettled the Railroads in that country, but it seems not. Our valuable exchange the *Journal des Chemins de Fer et des Mines*, has even come more regular since than before the revolution, and what is not a little pleasing to a republican the *red mark* of royalty has disappeared from the wrapper."

"The atmosphere is an ambient mantle which wraps the earth in its soft embrace. Its direct height from the surface of the earth is calculated to be fifty miles. Although the atmosphere is such a beautiful and transparent substance, yet it is not a simple substance. It is composed of two gases perfectly opposite in their natures singly. The one gas is named oxygen and the other nitrogen. The atmosphere is composed of 79 parts nitrogen and 21 parts oxygen, and although many gases have been discovered and combined, yet no other combination and no single gas will sustain life for any length of time but the air, and bountiful is our Creator who has supplied our earth with such a quantity of it."

"The Committee of the U. S. House of Representatives appointed to examine into the merits of Whitney's project for a Railroad to the Pacific, have reported favorably, only one of the Committee reporting against it."

"The expedition in search of Sir John Franklin has reached Buffalo, New York, where it is to meet some persons from Montreal, who, together will set out for Hudson's Bay via Detroit, and the Salt St. Marie, in the prosecution of the voyage of exploration. Sir John Franklin set out on this his last voyage of discovery in the year 1845."

"The body of a young man named Bruce has been discovered by clairvoyance in Boston. He had been missing for some time and a Miss Freeman, the clairvoyant, it seems mentioned some singular circumstances relative to his death. There is something essentially wrong in placing confidence in such nonsense. It pains us to think that with all our boasted civilization, so much superstition should still exist."

"An inexhaustible amount of Iron Ore has recently been discovered in Schuyler county within a mile of Illinois River. Samples of this ore were sent to Pittsburgh, and on trial found to yield a rich percentage. A company from Pittsburgh has since visited the ground and in conjunction with citizens of the Schuyler. are making arrangements to erect a number of furnaces with a view of commencing operations at an early day."

"Patent issued. to Charles Goodyear, of New Haven, Conn. for improvement in making hollow articles of India Rubber."

THE COVER

The painting on the cover depicts the apparatus used by C. J. Davisson and L. H. Germer to prove the wave nature of the electron (*page 50*). The diagram above the apparatus shows the path of the electrons which were directed at a crystal to obtain the proof.

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SCIENTIFIC AMERICAN

MAY 1948 VOL. 178, NO. 5

MAN OF THE AMAZON stands in a swamp on one of the valley's ill-defined river banks. At flood the river is as much as 400 miles wide.

THE FUTURE OF THE AMAZON

Four hundred years of civilized invasion having failed to extract its vast wealth, the Hylean Amazon Institute will now try using the scientific method from within

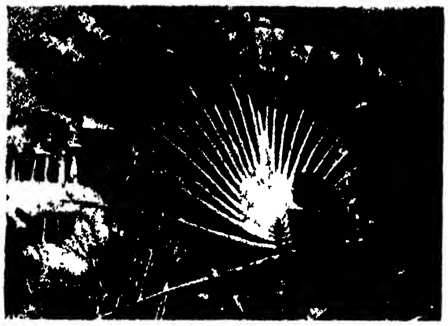
by Peter van Dresser

LAST month a group of scientists representing 10 American nations met in the little town of Tingo Maria, Peru, a garden spot at the headwaters of the Amazon River. There they formally organized an international enterprise. Its objective is to open a new frontier for a hungry world in the vast, unconquered Amazon Basin. The name of this "hemispheric TVA" project is the Hylean Amazon Institute. Its sponsor is the United Nations Educational, Scientific and Cultural Organization. To civilize the wild, rich Amazon and open it to colonization would itself be a gigantic achievement. But the project is perhaps even more significant as the world's first laboratory for international cooperation at the working level. Never before have nations pooled their science and technology to explore an entire subcontinental region and make it bloom for mankind.

The project was proposed just two years ago by a Brazilian biologist, Paulo Carneiro. UNESCO, then in session in Paris, at once warmed to his proposal. At Belem last August, 10 nations—the United States, Brazil, Peru, Venezuela, Colombia, Bolivia, Ecuador and British, Dutch and French Guiana—outlined their plans, and in November UNESCO officially approved them. To start preliminary studies, UNESCO appropriated $100,000, Brazil $600,000 and the eight other Latin American nations will raise about $100,000 more. A headquarters staff of five scientists, temporarily at Belem, the Brazilian seaport at the mouth of the Amazon, is now mapping out the tasks to be undertaken in the various sciences.

The Hylean (from the Greek *hyle*, meaning wood) Amazon Institute is an enterprise of breathtaking scope. Its purpose is not to gouge raw material and food out of the untamed forest. The history of the Amazon River valley is a long chronicle of failure in such endeavors. Wave after wave of expeditions of exploitation has washed up the valley, slaughtering forests, recklessly spending dollars and lives, only to be swallowed up in the overwhelming jungle. The new Institute will try a more thoughtful and subtle approach. It represents basically an attempt to apply the skill and weapons of modern science to making the jungle habitable and fruitful. Its strategy is to study the region's physiography, natural history and ecology (in this case, the relationship between the environment and man) and to evolve a process whereby man will learn to live harmoniously and richly in the environment instead of fighting it.

One of its first tasks will be to disprove the common notion that the Amazon Basin is a hostile, impenetrable wilderness. In part, the conventional view of the area as a steaming tropical jungle is correct. The river valley itself lies dead on the equator, and it is drenched with 100 to 200 inches of rain a year—five times the



A WATER PALM stands alone among hundreds of other species, complicating the problem of forest harvest.

SNOWY EGRET is part of the valley's intricate ecology. But the valley's wealth lies in its botanical life.

PALATIAL RUIN remains of grandeur of Manaos, headquarters of the first great Amazon rubber boom.

annual rainfall of the northeastern United States. Much of the waterway is lined with broad swamps. In the wet season, the swollen river rises 40 or 50 feet and overflows its banks, spreading out in some places to a width of 400 miles. The Amazon Basin's 2.6 million square miles are believed to contain fewer than one million people, although no census-taker has ever ventured far enough from the navigable waterways to count them.

Withal, it is a region of tremendous potentialities. Only a small percentage of the total area is jungle or swampland. This great watershed, which occupies a fifth of South America, is the largest single fluvial region of the globe, and at the same time one of the most richly endowed. Its land area, almost twice that of the Mississippi drainage basin, is nearly as large as the whole United States. It is drained by the most extensive system of watercourses in the world. The central river is navigable by ocean-going steamer for 2,300 miles, a distance equal to the span of the South Atlantic from Cape São Roque to Dakar. Its numerous tributaries—many of them major rivers in their own right—provide many thousands of navigable miles for steamboats and thousands more for smaller craft. Its lands are covered with an incredibly rich and diverse mantle of plant life, ranging from equatorial jungle and treeless savannah to upland forest and prairie. Its mineral deposits are probably at least as extensive as those of the United States; they include metallic ores from iron-rich hematite through the rare alloy elements to silver and gold, economic earths and clays, piezoelectric quartz and industrial diamonds.

For over 400 years this world of Amazonia has been known to the West. In 1541 Pizarro's lieutenant Orellana, traveling down the eastern slopes of the Peruvian Andes in search of La Canella—the fabled cinnamon spiceland—launched a crude caravel on the upper Rio Napo. Thus he unwittingly began an epic voyage which did not terminate until he and his ragged troop of men had sailed the three thousand wilderness miles to the broad Atlantic mouth of the *Mar Dulce*, as the river was then called. There they rebuilt their vessel and beat their weary way northward to Cuba. Orellana named the river Amazonas after a battle with a savage tribe whose women, according to his report, fought alongside the men.

In the centuries following, this equatorial world saw other epics of geographic reconnaissance by Spanish and Portuguese adventurers. The great naturalists—Martius, Baron von Humboldt, the Englishmen Bates and Wallace, the revered Agassiz and scores of others—made their pilgrimages there over the course of the nineteenth century. By the twentieth, highly organized expeditions, equipped with wireless, aircraft and the intricate paraphernalia of modern biological and physical science, were carrying on the tradition of exploration in this vast wilderness vivarium of plant and animal life.

It is a strange fact that in spite of this long history of exploration, and an equally long one of attempted colonization and development, the heartland of Equatorial America remains today one of the largest blank spots on the human and economic map. In the centuries during which other migrations to the Western Hemisphere grew from trading settlements to modern states with complex economies and populations in the tens of millions, the enormous alluvial plain of the Amazonian watershed has steadily declined in importance. Its population today, in fact, is probably considerably less than it was a century ago.

The story of the great rubber boom illustrates how ingloriously the Western mercantile world has failed in efforts to achieve a firm foothold in Amazonia. For generations the milky sap of various trees native to the American tropics had been utilized in a crude way for making waterproof garments and vessels. Orellana himself was probably the first Westerner to learn of the properties of these trees, since his homemade boat was caulked with a mixture of wild-cotton fiber and rubber. With the inventions of Goodyear and the rapid expansion of pneumatic-tired highway travel in America and Europe from the 1880's on, the latex of the wild rubber plant *Hevea brasiliensis* was suddenly in demand as a major industrial raw material. An apparently insatiable world crude-rubber market at 50 cents a pound sent a wave of "forty-niners" up the Amazon and on into the Purus, the Acre and the Jurua valleys. Trails were hacked through the wild-rubber territories; strings of trading posts, camps and steamboat landings were set up. Forests along the river banks were felled to fuel the steamboats. Thousands of native and immigrant *seringueiros* patrolled the wilderness, tapping the scattered latex-yielding trees, coagulating the milky sap over the smoke of urucury-nut fires in jungle-clearings, and bringing the great balls of dark gum for weighing in at the trading posts and fazendas.

For a while it seemed that the long-imagined development of Amazonia was at hand. Vast amounts of the white gold flowed down the great yellow river every year. Handsome plantation homes appeared here and there on the banks of remote watercourses. The fabulous city of Manaos, with its three million dollar baroque opera house, its paved streets and water system, sprang up at the confluence of the Rio Negro and the Amazon—trading capital of a million square miles of equatorial wilderness. An English company financed, at gigantic cost, the *tour de force* of the 220-mile Madeira-Mamore railroad.

But the period of the rubber boom

passed and left little permanent mark on the land. When rubber trees transplanted from Brazil to East Indian plantations matured, Amazonia's wild rubber declined sharply in value. Ill-fed and disease-ridden *seringueiros* and *caucheros* living in temporary forest encampments could not compete in output or in quality with the product of organized plantation labor in the long-settled island tropics on the other side of the world. In 1912 the last heavy shipment of crude rubber went down the river. The jungle reclaimed the encampments and trails. The fine plantation homes tumbled to ruin. Spectacular Manaos lost half its population almost overnight.

THE picture today, a generation later, has changed but slightly. Amazon river trade has recovered to some extent.

NATIVE HOMES are nearly lost in the jungle overhanging banks of one of Amazon's uncounted tributaries.

A few forest products such as Brazil nuts, piassava fiber, palm-nut oil, are gathered for export. Steamboats and towboats still ply the river, although in diminished numbers. An occasional mail and passenger plane drones up the valley, linking the interior towns more closely with the administrative and business world of the coast. Here and there a scientific pioneering project, such as the Ford rubber plantation on the Tapajoz, or a medical or sanitation program backed by government, hints of new achievement. But on the whole the Amazon is still essentially the virgin wilderness traversed by Orellana 400 years ago.

One conclusion that may be, and often is, drawn from the evidence is simply: Amazonia is uninhabited because it is uninhabitable. But a strong school of Amazonists, basing their conclusions on a tough and scientific appraisal, reject such pessimism. The total area of uninhabitable swamplands amounts to no more than one per cent of the entire watershed. Some 10 per cent is open savannah, ideal for livestock husbandry, and a big proportion of the forest is well-drained and reasonably insect-free. Though humidity is high, temperatures are moderate, varying from 68 degrees to 93.

What is needed to transform this river-universe into a working part of the civilized world, according to the new school of Amazonists, is a revolution of our attitude toward it. In the past, this, like most other "colonial" regions, has been regarded as a mine from which the raw material required by an alien industrial economy—crude rubber, vegetable oils and fats, fibers—are to be extracted in maximum quantities and at minimum cost, with little regard for the socially destructive by-products of such a process. A new and broader vision must guide future efforts. Amazonia itself must be developed as a well-rounded, integrated economic community.

The drafting commission for the new Hylean Amazon Institute has broken down its unprecedented task of geotechnic reconnaissance into three phases covered by the natural sciences, the social sciences and medical science. During the first year the survey staff is undertaking the preliminary charting of the lines of attack.

The first phases may be thought of as a consolidation and extension of the knowledge gained during the labors of generations of botanists, zoologists and other natural scientists who have worked in the Amazon valley system. The cataloguing of a complete scientific reference library of Amazonia is a formidable project in itself, owing to the immense amount of published material. Martius' great encyclopaedia of Brazilian flora alone fills 40 volumes and required the first half of the nineteenth century to complete.

But this is the simplest first step; from here the agenda projects a program of comprehensive botanic and zoologic exploration. A chain of regional experimental gardens and forest reserves will be established. Specimens of insects and plants must be collected and classified. A "census" of animal species must be made. Extensive ecological studies must be pursued in the field to determine the interrelations of the teeming life of the various subregions.

And of course, underlying the investigation of life phenomena there is to proceed the even more basic study of the land itself—its geology and physical geography, the nature of its myriad soils and their mineral substructures—all to be tied together cartographically by the great new 1:1,000,000 Amazonia map now being prepared by the Brazilian Geographic Council.

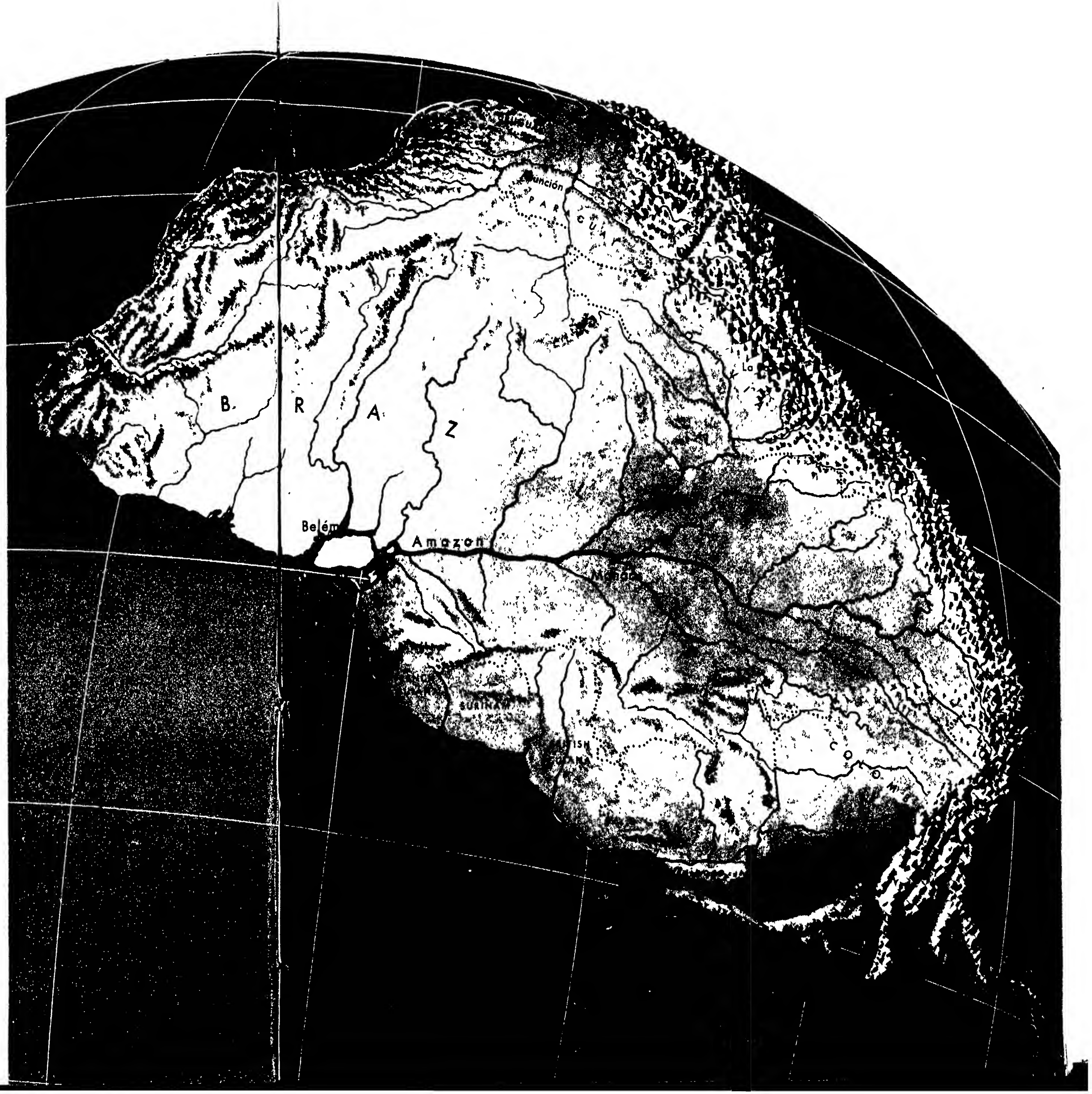
The task outlined for the social sciences is equally broad—and perhaps even more interesting. It is generally conceded that the "problem of the Amazon" may be summed up as the problem of establishing and maintaining a vigorous and stable population in the region. Without such a population, "development" in any sense—mercantile, economic or cultural—is impossible. Yet it is just in this task that the methods of Western civilization in Amazonia have so far proved inadequate.

One elemental fact that must be faced is this: any permanent and distinctively Amazonian society must be predominantly forest-dwelling. To think in terms of "clearing the jungle," as the Westernized colonist has been apt to do, and then to attempt to impose upon it a temperate-zone pattern of agriculture, is utterly impracticable. Only by maintaining unbroken the mantle of native climax-vegetation can the fertility of tropical humus be maintained, and the prodigious growth-power of tropical plant life be utilized. The end products of that growth—the wealth of fibers, woods, resins, oils, waxes, fats, fruits, tubers, botanic essences—must form the raw materials of a specialized technology capable of producing in abundance the foodstuffs, the textiles and clothing, the buildings and dwellings, the tools and utensils, of a true Amazon-based society. The members of such a society must know how to live comfortably, and to maintain health and vigor, in the rain-forest. They must be master of many arts and skills appropriate to their environment.

It is probable that even the population-density patterns and the modes of exchange and distribution of such a society must be very different from Western norms. One of the most baffling characteristics of the Amazonian jungle, from the point of view of commercial exploitation, has always been the scattered distribution and intermixture of plant types. For example, the valuable hardwoods which are there in abundance never occur in dense stands suitable for mass cutting and lumbering operations. In a square kilometer of heavy forest growth, the same species of tree may not be repeated twice.

To utilize resources of this kind, over a large area, a corresponding diffusion of manpower would seem indicated. The uneconomic cost of mass-transportation facilities except along waterways—would combine with this factor to suggest a pattern of numerous, well-distributed communities, each largely self-sufficient in the production of the bulk necessities of life, each harvesting the rich and varied crops of the surrounding forest. The populations of these communities would consist largely of woodsmen or "forest farmers," and of craftsmen and technicians trained in extracting, refining and processing the wealth of botanic substances.

What better parent stock for the breeding of such a forest-adapted culture could be found than the 300,000 to 400,000 native Indians in the region? Accordingly, the anthropologists of the new Institute plan a complete study of the patterns of the native cultures, folklore, language and intergroup reactions. They will seek to understand and evaluate the way of living that subdued the ever-present threat of



THE GREAT VALLEY, shown in a spherical projection from the north, covers 2.6 million square miles of the South American continent. It is roughly bounded on the west by the Andes, on the south by Paraguay, on the east by the Atlantic and on the north by the valley of the Orinoco. Rising from Andean glaciers, the Amazon flows 4,000 miles through the jungle to its delta. Its uncounted miles of tributaries are a measure of the valley's natural wealth. They drain away an annual 100 to 200 inches of rain which, together with equatorial sunlight, is a principal element of its botanical environment.

malaria with dietary regime and quinine long before Western medicine was able to cope with it; that worked out a surprisingly subtle empirical chemistry of botanic drugs; that laced the Amazon world with a network of *igarapé* ("canoe-paths") over which native commerce and intercourse flowed constantly. The goal of the Institute's social science program will be to develop a technique whereby the science and skill of Western civilization may be grafted intimately and understandingly into these indigenous folkways.

The native forest agronomy of the interior, with its specialized food plants such as cassava, the plantains, the avocado, the Brazil nut, is to be enriched through the application of principles of plant-breeding, soil chemistry, nutrition and by the careful introduction of new and suitably adapted food plants. The native fishing practices are to be studied and improved. Native handicrafts and native technology are to be revived, stimulated and gradually extended in scope and power.

An interesting example of this approach is the "pa agronômica" process for hand-coagulating native latex. This process, worked out at the Belem agricultural experiment station, yields rubber comparable to that produced in the industrialized East Indian plantations, yet it may be employed by the native *seringueiro* on his own small holding. It is proposed to redevelop the moribund Amazon rubber industry on a basis of decentralized production on many independent forest-farmsteads, using improved methods and, of course, improved strains of *Hevea* bred at the experiment stations.

To direct this broad movement of grass-roots economic maturization, the Institute's directors foresee a network of rural libraries, museums, technical schools, experiment stations and colleges, reinforced by mobile educational teams working with the most advanced visual aids and pedagogic techniques. Native educators and technicians trained in these institutions are to carry their skills into the deepest backwoods. Concurrently, medical science is to work to strengthen the population through the elimination of infectious diseases and the improvement of nutrition.

Along with the pattern of native forest agronomy, there may be gradually evolved a system of extractive industries forming a link with the industrial economy of the West. Rubber, methyl alcohol, acetic acid, glycerine solvents, soaps, plastics may be obtained from the organic raw materials of Amazonia, once adequate manpower and transport become available. However, in the planning and financing of these industries careful study is required to eliminate the destructive effects which have always accompanied the introduction of the high-energy, high-cost economic operations of the West into an area of less intensive development.

The question of energy sources for such industries (and for extensive river navigation also) presents an interesting related problem. Coal and oil deposits appear to be the one deficiency of the region. Hydroelectric power, while potentially abundant, requires massive investment in structures and equipment that the economy of the valley will probably not be able to sustain for many years to come. Atomic energy may in the not-too-distant future offer an alternative, but it would inject a factor of global economy and strategy whose impact on the region would have to be carefully studied. In the immediate future scientific utilization of fuel wood, either directly under steam boilers or in the form of alcohol or distillation gases, may be possible for specialized enterprises. And for the long run, Amazonia appears to be an ideal territory in which to pioneer in the use of wood as an ever-replenishing source of energy in the form of charcoal, alcohol and the like.

In total, the Institute's program is one of the most challenging ideas on the horizon of science. Up to the present, the impact of Western civilization on other cultures has been disruptive, often to the point of annihilation. Amazonia, although it too has suffered, remains by far the greatest richly endowed region substantially untouched by this process. Even the fabulous period of the wild rubber boom seems in perspective a mere frenzied hacking at the Hylean wilderness.

THUS the Amazon offers a virgin laboratory in which the sciences and social techniques of our civilization perhaps grown somewhat more mature, may try their skill. The stakes in this effort are the opening up of a land very nearly the size of the United States—and at least equally endowed in natural riches—in a period of explosive economic dislocations and population pressures. Perhaps even more important, there stands the possibility of working out a pattern for human occupancy of the land which may serve as a model in many parts of the globe.

Peter van Dresser is a city planner and writer.

SKULL of Plesianthropus was found embedded in limestone. The face appears pointed because jaw is missing.

THE MAN-APES OF SOUTH AFRICA

Recent fossil finds reconstruct a possible direct ancestor of man who lived seven million years ago

by Wilton M. Krogman

MAN is known to have existed on this planet for at least one million years. He can trace back his line with fair confidence to *Pithecanthropus* and *Sinanthropus*, the Java and China fossil men, who from the evidence of bones are the earliest known creatures that may be considered truly human. There the trail exasperatingly stops. Beyond the fragmentary remains of these generalized human beings, the genealogy of man and his anthropoid ancestors dissolves into a pathless unknown.

Superficial resemblance has argued since Darwin that man is an offshoot from the anthropoid apes. But the case remains unproved; indeed, the more it is examined, the less convincing it becomes. Between the most highly developed modern anthropoids and the most primitive living men exist differences so basic that the two can be connected only by imagining a series of "missing links" of an unimaginably paradoxical pattern—here progressing, there retrogressing, and in some characteristics suddenly striking off in an unpredictable new direction.

The search for evolutionary links between man and his elusive ancestors, whoever they may have been, is one of the most fascinating in all science. It has engaged the unremitting attention of fossil hunters for a period of more than half a century. Until very recently, however, they had unearthed disappointingly few clues.

Now they have picked up what appears to be a very warm scent indeed. In South Africa, during the past few years, Dr. Robert Broom has discovered fossil bones that have compelled us to recast our thinking as to when and where man made his first appearance on the earth The bones make up a number of sub-human skeletons These South African "Man Apes," of which the best-known is named *Plesianthropus* (from the Greek *plesio*, meaning "close to," and *anthropos*, "man"), are truly astonishing connecting —not missing!— links between man and the ape-like forms from which he arose. Notice that the word is "ape-like." If we adhere to the term "ape-like" or "anthropoid" in describing man's ancestors, we shall avoid prejudging the question of man's exact relationship to the apes.

The Plesianthropus story begins with a dramatic prologue in 1925. Dr. Raymond Dart, professor of anatomy at the University of Witwatersrand, was keeping a sharp eye on the digging in an old limestone quarry near Taungs, in Bechuanaland, where many fossil apes had been found. There, from the solid rock, was dug one day in 1925 a limestone cast of the inside of a skull. Its shape was so unusual that Professor Dart pressed on; soon his diggers unearthed the front half of a skull top and an almost complete facial skeleton, all clearly belonging to the same individual. The skull had a full set of deciduous or baby teeth, plus the first permanent molar. The fossil was therefore that of a youngster about six human years old.

Some parts of this skeleton were definitely ape-like But others, especially the teeth, were very much like man's. Indeed, if the teeth had been found separately, they would have been pronounced human. The whole skull showed such an amazing blend of anthropoid and human traits that Dart immediately concluded that he had found an important intermediate form. He gave it the name *Australopithecus africanus* (meaning southern ape of Africa).

Dart's find was fascinating but inconclusive. It is hard to be sure about an immature skeleton: the skulls of a young anthropoid and a young child are much more alike than those of adults.

Then, in 1936, Dr. Broom, chief paleontologist of the Transvaal Museum in Pretoria, picked up the track again. At Sterkfontein, in the Transvaal, he found several fossil fragments which fitted together to form part of a skull. It was evidently close kin to Dart's Australopithecus, but this skull was adult. Broom first called his find *Australopithecus transvaalensis*, and later renamed it *Plesianthropus transvaalensis*.

chewed his food with a rotary grinding motion, like man, instead of chomping it, like the anthropoids. (Lil' Abner notwithstanding, human beings are not in the habit of "chompin'" their food.)

What did Plesianthropus look like? His facial profile was relatively man-like; it was losing the anthropoid slope. The bony ridges above his eye sockets were less protruding and he had the beginnings of an arching human forehead. Also like man, he had fairly slender cheekbone arches. The front surfaces of his upper jaw were vertical, not slanting as in apes. The "simian shelf," a characteristically anthropoid platelet of bone on the under side of the lower jaw, had all but disappeared. And on the front of the lower jaw was a little knob—the beginning of a human chin.

Plesianthropus' bones retained many anthropoid features. The side teeth in his upper jawbone, for instance, were arranged like an ape's. The contact-line, or "suture," between the two bones of the hard palate, which in man usually closes at birth, appears to have delayed in closing, as with an ape.

Below the neck, Plesianthropus looked like an incompletely developed biped. His elbow joint did not flex as freely as man's; his arms seem to have been permanently bent. His anklebone, intermediate between a human and an ape-like form, indicates that the ankle may have been designed for weight-bearing, as in an erect man, but that the foot may still have possessed a grasping big toe. The bone in the center of his palm suggests a hand freed from locomotion but with limited flexibility for manipulation. His thighbone and hipbone, in the opinion of some, were mechanically adapted for standing, walking and running in the erect position.

Did Plesianthropus actually walk upright? All the evidence points to the likelihood that he did. One significant sign is the position of the foramen magnum and the occipital condyles. These structures form the joint where the skull rests on the backbone. In anthropoids, this joint is far back on the skull-base. But in man, it is in the middle, so that his skull is balanced squarely on the spinal column. Plesianthropus was well-advanced toward this balanced position. His foramen magnum was much farther forward than that of the anthropoids, but not as far forward as man's.

As to the quality of Plesianthropus' brain and his abilities, we have little evidence. The casts of the inside of his skull do not show his brain configurations in any accurate detail. They tell us only the approximate size of regions in his brain. From his study of the brain casts and skeleton, Broom's associate Schepers concludes:

"These fossil types were capable of functioning in the erect posture, of using their hands in a limited sense for skilled movements not associated with progression, of interpreting their immediately visible, palpable and audible environment in such detail and with such discrimination that they had the subject matter for articulate speech well under control. . . . They were also capable of communicating the acquired information to their families, friends and neighbors, thus establishing one of the first bonds of man's complex social life. With all these attributes, they must have been virtually true human beings, no matter how simian their external appearance may have remained."

In contrast with this extreme interpretation is the more conservative—and more acceptable—view of the English anthropologist W. E. Le Gros Clark. The endocranial casts suggest to him "that the mental powers of the Australopithecines were probably not much superior to those of the chimpanzee and gorilla." Nonetheless, on the basis of another piece of evidence, Le Gros Clark concedes that their intelligence was "definitely in advance" of that possessed by the modern apes. In the same cave with some remains of Australopithecus were found the crushed skulls of baboons, suggesting that the mental powers of Australopithecus were great enough to enable him to hunt and kill monkeys.

FRONT of Plesianthropus' skull shows small brow ridges and arching forehead of man-like anthropoid.

What does our evidence on the Australopithecines add up to? It is this: that in the Pliocene period, about seven million years ago, there lived a form that was intermediate between anthropoid and man. He had a brain near the anthropoid, a dentition practically human, and a general skeletal build well-adapted to the human upright position and locomotion. The Australopithecines fulfill almost every requirement of a real connecting form. Moreover, they show that the rate of evolution differs in various parts of the body: thus dentition is ahead of long bones, and long bones are ahead of brain.

We are certainly not sure of the precise evolutionary position of the Man-Apes. The problem is: were they a link in the direct line to man, or were they abortive offshoots of an attempt by an ape to make the grade to man's estate? The first alternative seems to me the more likely.

ANY chart of human and anthropoid evolution must be tentative and speculative. Let us draw one picturing a set of reasonable possibilities. We can start (we must start somewhere!) with *Propliopithecus*, a fossil anthropoid found in an Oligocene formation of Egypt which is about 30 million years old. He was not an ape, mind you, but most likely a common ancestor of apes and man. From Propliopithecus may have come *Dryopithecus* and *Sivapithecus*, anthropoids of the Miocene and Pliocene of Europe and India. They in turn, still according to our hypothesis, were ancestors of Plesianthropus and his cousins. The evidence of Plesianthropus' teeth strongly suggests that he and his fellows may have been ancestors of the first true men, Pithecanthropus and Sinanthropus. (*Gigantopithecus* of Java may fit into the line here, but there is some doubt whether he was anthropoid or hominid.) From the Java and China men, in turn, via Solo man of Java and Neanderthal man of Europe, finally came Homo sapiens.

Where do the apes fit into this picture? There is increasing conviction that the modern anthropoids (gibbon, orangutan, chimpanzee and gorilla) have arisen independently of man. Somewhere in the Oligocene or the Miocene, their ancestors split off from the common trunk to form separate branches. They may have split off from Propliopithecus or, more likely, Dryopithecus and Sivapithecus.

This chart represents only one of several plausible possibilities. The Australopithecines may, indeed, have been an offshoot from some still undiscovered ancestral form. The modern apes and anthropoids may each have come from a different ancestor. But the chart offers a tenable present view. If its chain of reasoning be true—and I suggest that it is reasonably so—then human evolution is almost a straight-line parallel of anthropoid evolution, with a basic split-off of the several lines in the Oligocene period 30 million years ago, ± a few million.

It is the South African Man-Apes who have pointed the way to this conclusion. In effect they have emancipated man from a presumed simian ancestry. "Family tree" may be a misnomer. Perhaps we never were brachiators, *i.e.*, swingers-through-the-trees-by-our-arms. It is entirely possible that for millions of years we've walked erect, striding head up toward our evolutionary destiny, whatever it may be.

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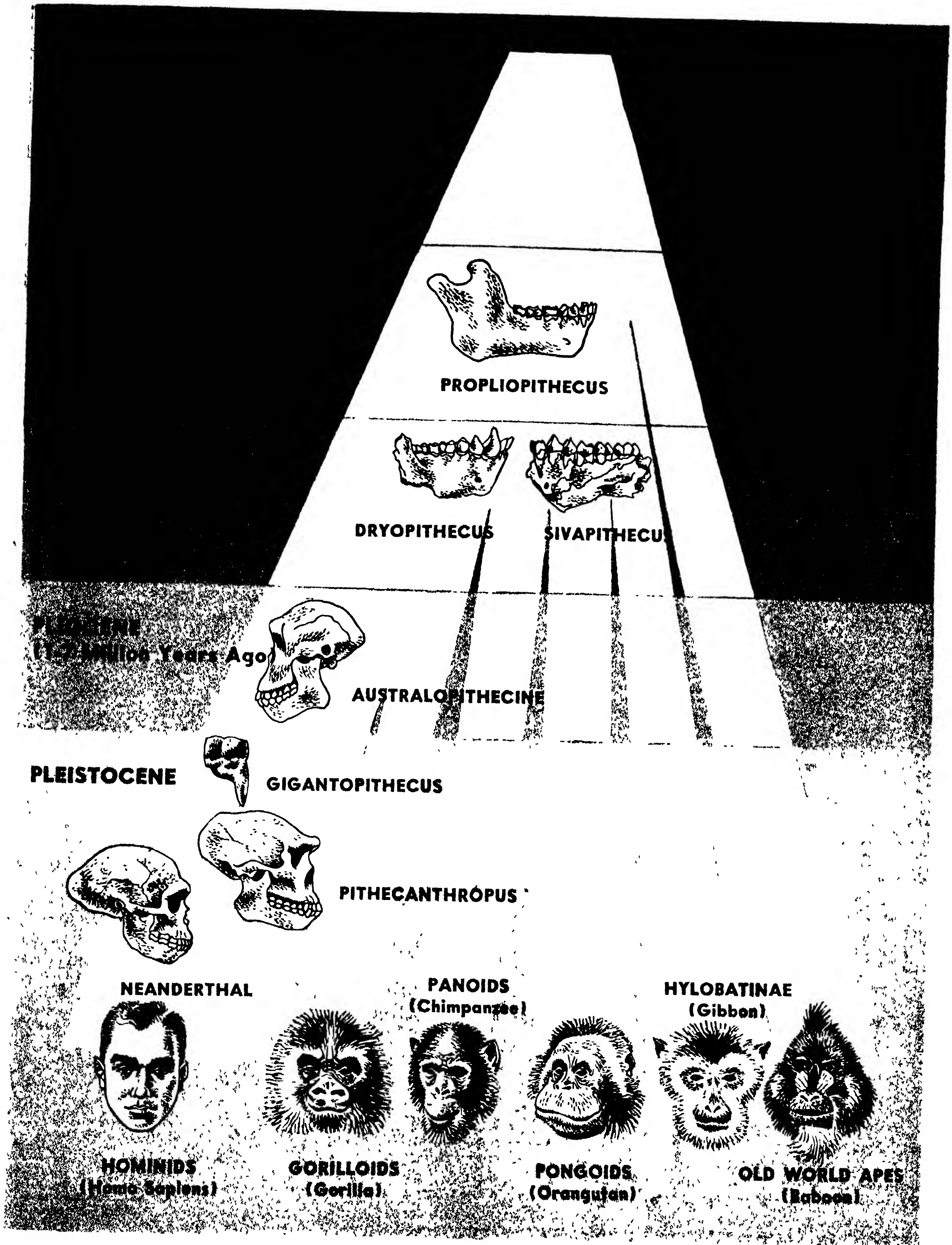
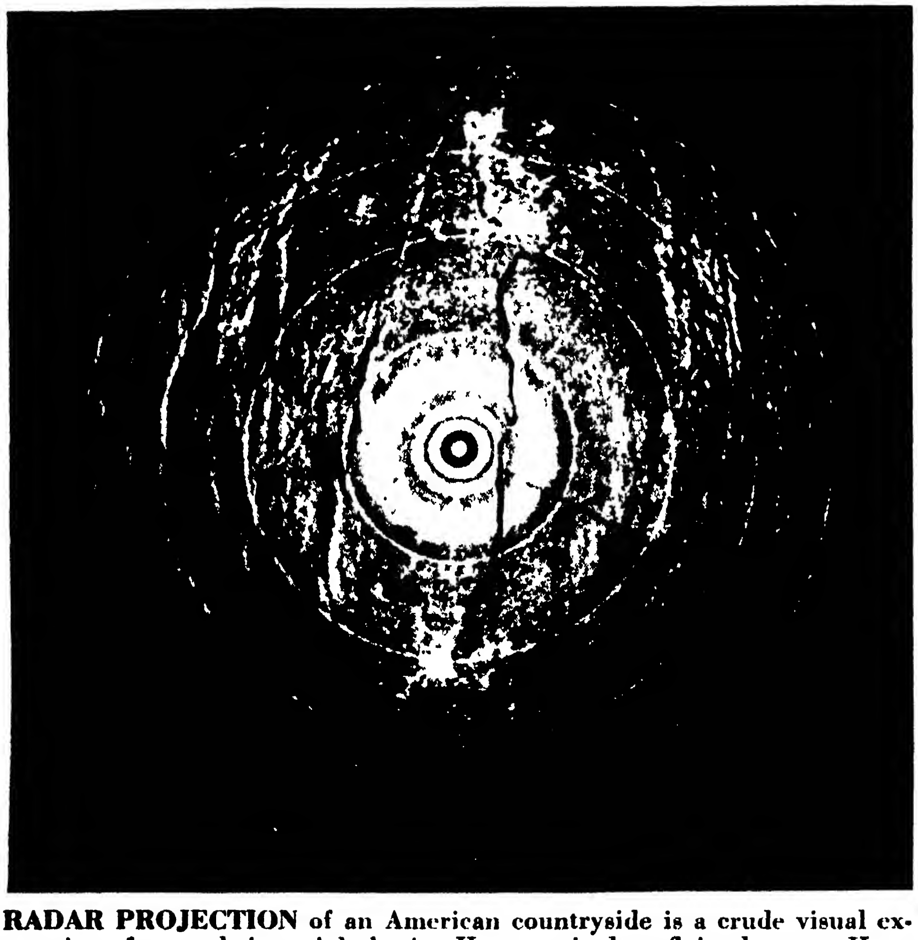


EVOLUTION of man and apes appears to have proceeded from common ancestors in the Miocene and Oligocene periods. Here the Australopithecines are in the direct line of human descent. Complete fossil skulls are shown where reconstructions have been made. Incomplete fossils such as Gigantopithecus are not drawn to scale.

CONCERNING "SOCIAL PHYSICS"

The quotation marks indicate that it is not an accepted science, although it may well become one. Its principal concept: the behavior of people in large numbers may be predicted by mathematical rules

by John Q. Stewart



RADAR PROJECTION of an American countryside is a crude visual expression of one rule in social physics. Here an airplane flying between Hartford, Conn. (*bottom*) and Springfield, Mass. (*top*) sweeps the ground with a beam of microwaves, translating the reflected signals into an image on a cathode-ray screen. Since areas where many buildings are concentrated reflect the signals better than those with fewer buildings or no buildings at all, the most densely populated areas appear as the brightest spots on the screen outside of the overexposed central part. This imperfectly depicts the fact that people tend to concentrate by an inverse-square relationship like that of gravity. The formula used in social physics, explained in text, is Pp/d.

A GIANT observer who himself was as big as the earth could easily consider a man as being no more than a molecule. From such a vantage point, an observer equipped with appropriate devices for measuring population densities and movements might discover that, like molecules in a gas, groups of men obey certain simple physical laws. The point of view would be favorable for formulating an exact social science—a "social physics."

Molecules are unable to study themselves with such detachment. Nevertheless, man is strongly tempted to try to find some mathematical order in human relations. More than one investigator has sought to apply the analogies and precision of physics to the study of societies. The term "social physics" is at least as old as the nineteenth century French philosopher Auguste Comte, although he contributed nothing to the subject but its name. Today social physics is still only a science in the making. It still has far to go before it is ready for uncritical acceptance. But already its barrier-breaking results unite demography (the study of populations) with phases of economics, and both of course with physics.

But what has physics to do with people? Men, after all, are more than molecules. Can we advance the study of human relations by forgetting that they are human? Or, to put it another way, can we roughly approximate satisfactory over-all solutions of mass sociological problems by an analysis that averages the conflicting desires and the varied characteristics of individuals into a uniform mathematics?

I am confident that we can. People can be counted. They exist in space and time. Their distances apart can be measured. Their activities are subject to mechanical limitations which can be described. True, an individual human being is a complex, often unpredictable organism. But the physics of atoms is subject to similar uncertainties. The famous indeterminacy principle, stated by the German physicist Werner Heisenberg, means that the motions of individual corpuscles cannot be described with indefinitely great precision. The behavior of an individual particle is exceedingly hard to predict. Nonetheless the physicist makes progress because the *averaged* motions of a group of corpuscles conform to mathematical formulas or "laws." In the same way, human behavior can be averaged.

When the physicist attempts to study people in their societies by comparing them to molecules in fluids, his difficulty is not that there are too many people but too few. If reduced to the size and density of molecules in normal air, the entire world's population would comprise a cube only a thousandth of an inch on a side. To reduce the planet to this size, our physicist must be a coarse-grained giant of astronomical dimensions. Little wonder that professors of history, politics and eco-

nomics are likely to oppose the notion of loosing such a bull in such a china shop. But he was already there, even before Hiroshima.

Here we should pause to define our subject. Social physics examines human relations in terms of space, time and number. In brief, it is the quantitative study of society. Its raw material is statistical observations about people. Whenever appropriate, it draws on mathematical physics for suggestions and analogies which seem usable as guides for discovering and organizing social concepts. It also uses such generally-accepted and well-tested sociological information as already exists. It includes, for example, the subject of econometrics, which is a union of mathematics, statistics and economics.

Thus much suitable material lies ready to hand. Indefatigable social statisticians, especially in recent years, have accumulated hundreds of shelves of numerical observations. For example, the sixteenth census of the United States, made in 1940, runs to more than 60 volumes and cost 50 million dollars to compile and publish.

WHEN analyzed, this material reveals some astonishing mathematical relations. George Kingsley Zipf of Harvard University has found, for example, that the number of telephone calls between any two cities in the United States is roughly proportional to the product of their populations divided by the distance between them. The same relation holds true for the number of bus passengers between cities and the number of railroad tickets sold. The enrollment of students from a specified state in any given privately endowed, "national" university or college tends to be proportional to the population of the state divided by its distance from the campus. Attendance at the New York World's Fair in 1940 from each state was proportionate to the population of the state divided by its distance from Flushing, Long Island. The number of obituaries from specified cities in the New York *Times*, the number of news items from other cities in inside pages of the Chicago *Tribune*, and the circulation of the St. Louis *Star-Times* in counties outside the city all show surprising agreement with the population-divided-by-distance rule.

The task of the social physicist is to invent new systems of concepts which fit such observational situations. In doing so, he is guided and encouraged by the glorious history of physics itself.

The present state of social studies may be estimated as little superior to that of physics at the time of the seventeenth century astronomer Johann Kepler. It was only three centuries ago that physics learned to supplement words with numbers. The entire body of knowledge of physical principles accumulated up to that time would not make a single lesson assignment now for a high-school freshman. Modern physics had its beginning in celestial mechanics. It advanced through three successive stages, typified by the names of three astronomical investigators: Tycho Brahe (1546-1601), Kepler (1571-1630) and Isaac Newton (1642-1727).

Tycho Brahe over laborious years accumulated many reasonably accurate observations of the positions in the sky of the planets, in particular of Mars. Because precise observation was far from being a routine requirement of science at that time, this Danish nobleman was a great pioneer. Kepler became his secretary and inherited his sheaves of observations. Kepler deserves an even higher place among the founders of modern science than he usually is accorded. He had a fanatical faith in number as a means of insight into physical phenomena. To modern scientists that seems no faith but obvious common sense -until someone suggests that number is equally important for social phenomena! Kepler made trials, errors, retrials—many of them cockeyed before he succeeded in stating the last of his three "laws" on the orbital motions of the planets. These are not general laws of nature but empirical statements of mathematical regularities which apply only to planetary motions. But when Newton sought to reduce all motion everywhere to orderly description, he needed only to think of Kepler's short mathematical statements, instead of having to essay the impossible task of carrying in mind many thousands of separate measurements. Newton, without much trouble, because he was "a giant who stood on giants' shoulders," carried mechanics to its third stage of rational interpretation of all known motions.

The phenomena with which social physics must deal are less tractable, and more intricate, than the harmony of the spheres. As already indicated, this is partly because we view them from the microscopic rather than the macroscopic level, being ourselves "molecules." What the student of the kinetic theory of gases calls a minor fluctuation in pressure may represent a terrific series of bumps to a lot of molecules.

In the modern study of society, no single individual has been a Tycho nor a Kepler, and no one investigator is likely to repeat the role of Newton. Thanks to the labors of the social statisticians, however, the Tychonic stage is unmistakably here. And the Keplerian stage is in progress.

The available numerical data on society include censuses of populations, vital statistics, tables of geographical areas and distances, rents, prices, wages, dividends, interest rates, studies of business cycles, public opinion polls, psychological tests relating to social behavior, quantitative observations in philology. So far only a very small proportion of this grand observational array has been reduced to concise mathematical regularities. The workers in this field are few, and fewer of them are sociologists or economists. Outstanding are the contributions of Professor Zipf of Harvard, whose original field was philology.

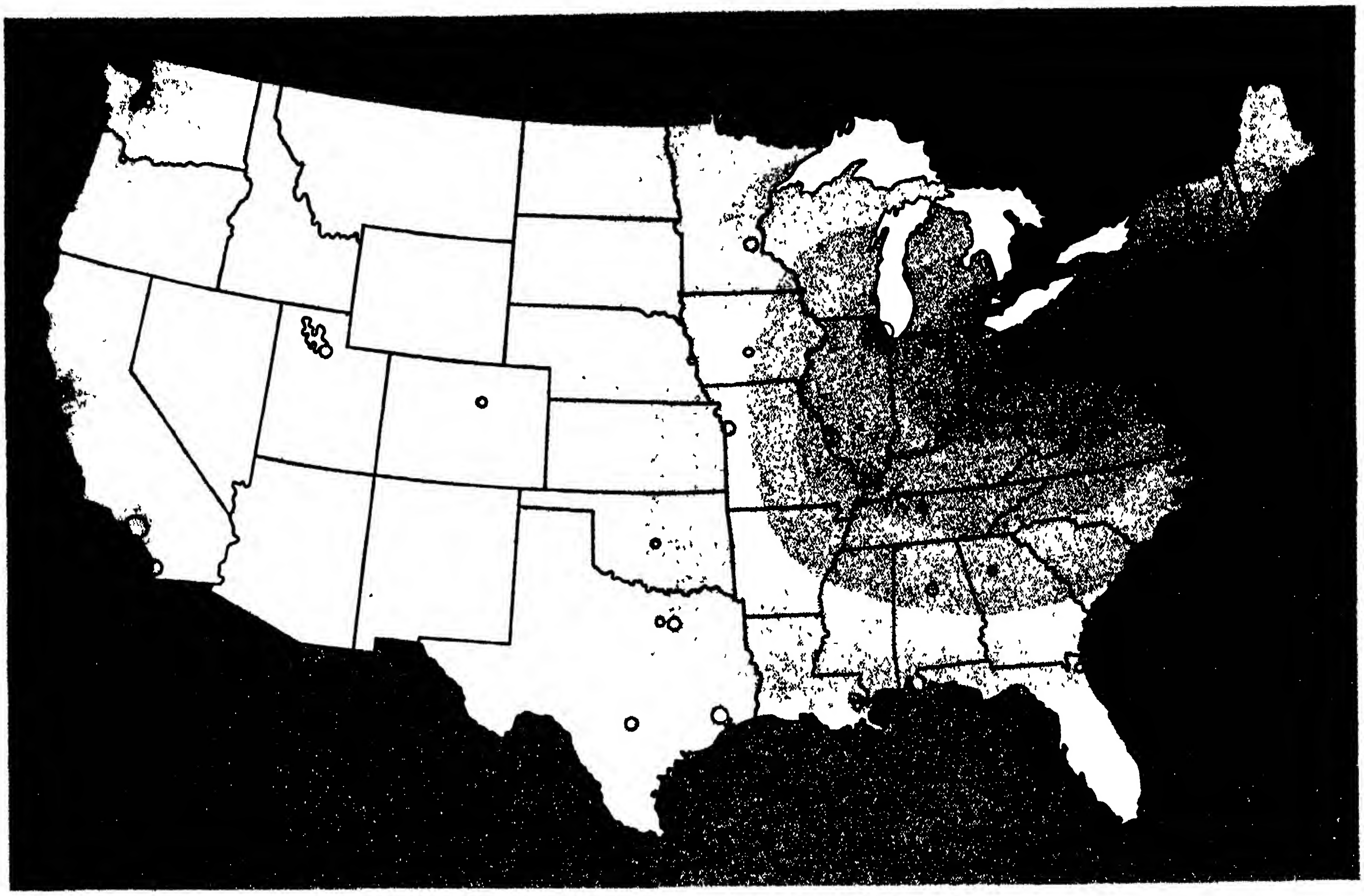
Professor Zipf has emphasized particularly the "rank-size rule." This rule shows a definite mathematical relation between the relative rank and size of institutions in a series. As applied to cities, for example, it determines that the second largest city in a certain group has $1/2^n$ as many people as the first; the third largest has $1/3^n$ as many as the first, and so on—n being a constant depending on the series considered. With n=1, this rule has applied with remarkable regularity to the populations of cities in every United States census since 1790.

THE writer cannot discuss all the empirical regularities that have been announced for social phenomena. But enough regularities exist to establish the conclusion that certain types of human relations, *on the average and only on the average*, conform to mathematical formulas resembling the primitive "laws" of physics.

When we come to the Newtonian stage of theoretical interpretation, we encounter our major difficulty. Scientists are prone to believe that every branch of study has its own peculiar relationships, most of which are not duplicated elsewhere. In this view, principles of physics could have no meaning in social study. This conventional view was emphatically opposed, however, by Gottfried Wilhelm Leibnitz, who was Newton's great contemporary and rival in mathematics, physics and philosophy. Leibnitz believed thoroughly in the transferability of ideas and relations from one field to another. A hundred years after both savants were dead, Newton's own law of gravitation became an instance of such transfer. A principle of exactly the same mathematical form as his law was found to hold in electrostatics, and again in magnetism

Now the same mathematical form serves to organize a wide range of observations about people. To see how it does, let us consider the principle in some detail. Newton stated his law in terms of the force between two attracting masses. The force varies as the product of the two masses divided by the square of the distance between them. It is often more convenient to state the same principle in terms of mutual gravitational energy instead of force. Force is a directed quantity—a "vector"—and therefore forces have to be added by trigonometry. Energy is a non-directed quantity—a "scalar"—and scalars add by mere arithmetic. Thus the gravitational energy between two masses varies as the product of the masses divided not by the square but by the first power of the intervening distance.

This important difference makes pos-



"POTENTIAL" in social physics is a measure of the influence of people on people. The influence of a city at a distance (example: the number of telephone calls made from it) is represented by its population divided by the distance. In this map New York City has the greatest potential. Its strength is indicated by number at the edge of each contour. The influence of other cities (*circles*), save those on the West Coast, is merely local.

sible the elegant solution of problems when several gravitating masses interact, as in the solar system. Joseph Louis Lagrange, the eighteenth century French mathematical physicist, was the first to appreciate this convenience. His method describes the influence of a body at any separated point in space as the body's "gravitational potential" there, and this potential, V, is proportional to the mass of the body divided by the distance. Thus the potential of the sun, whose mass is designated by M, at a certain point at distance d away from it, is M/d. If a planet, of mass m, is located at this point, the mutual gravitational energy of sun and planet would be Mm/d.

When there are several distant masses, the potential produced by each at any given point is computed as though the other masses did not exist. To obtain the total potential at that point, the separate potentials of all the masses are added up. This same pattern of related equations and concepts (and others not mentioned here) holds not only for gravitation, but also in electrostatics and in magnetism. In electrostatics, the symbols for mass, M and m, are replaced in the equations by the symbols for electric charge, E and e. In the theory of magnetism, we use pole strengths instead of charges or masses. Although the symbols refer to very different things, the equations are the same.

Now let us apply these equations to populations. In the place of mass or charge we substitute "population density." This term is actually derived from the physical concept of surface density; the analogous unit in electrostatics would be the amount of surface charge per unit area of the charged body.

Pursuing the analogy, we may take the density of population in a given area—say a city—as a measure of that population's influence, or potential, at distant points. By the equation we considered above, the influence of one city upon another would be proportional to the product of their populations divided by the distance between them, or Pp/d.

DOES this relation hold in fact? It does indeed, for a surprising variety of phenomena, as we have seen in the case of telephone calls and many other items of human commerce. There now exists a considerable collection of interesting statistics to confirm the "Pp/d hypothesis."

The population-divided-by-distance formula was originally used in connection with the geographical distribution of college undergraduates. Its close analogue with physics suggested the concept of a "potential of population" corresponding to gravitational potential. This in turn suggested study of the mutual "demographic energy" between cities. A diagram of energies between cities is very similar to one illustrating mutual gravitational energies between bodies in the solar system.

From census data on the distribution of people, a map can be computed showing potentials of population at all points. Such a map, like a topographical one, has contours outlining levels of equal potential. In the United States, potentials in general rise toward New York, except west of the Sierras. In Europe, Asia and South America, they likewise rise toward the great coastal cities; in Africa, toward the major river valleys.

As everyone knows, the proportion of city-dwellers in the United States has consistently increased. Should the total United States population ever reach 260 million, the indication is that the rural population, except doubtless for a small, stubborn remnant, will have disappeared. All the people would be living in 10,400 cities, and the largest city, probably New York, would have a population of 26 million. If the total population were to go on increasing beyond that highly problematical level, the larger cities would begin to eat up the smaller ones, and finally everyone would live in a single great city whose population works out as 6.250 million. But these extreme extrapo-

lations had better be regarded as just a little fun with arithmetic.

The map of potentials of population, however, is much more than a mathematical exercise. A completely accurate map, which must exhibit not only the major influences such as New York City but also local loops of potentials surrounding every sizable city, is laborious to compute and construct. When carefully done, it is highly rewarding, for it gives us some significant social quantities.

State by state, and even county by county, population averages along contours of equipotential run remarkably true to form. This is true, for example, of population densities in the region embracing the 28 states east of Colorado not including the deep South, *i.e.*, principally the Middle West, Middle Atlantic and Northeast. The density of rural population tends to remain constant along any given contour. When we move to a higher contour (*i.e.*, a higher potential) in the direction of New York, rural population density increases according to the square of the increase in potential. But densities of the rural non-farm population (*i.e.*, in villages) increase as the cube of the potential.

As the potential rises, the death rate, suicide rate and the median age in rural areas also tend to rise, while the birth rate falls. Especially interesting is the relation of economic statistics to the contours. In the 28 states, average nonfarm rents rise as the first power of potential, while values of farmland per acre tend to rise as potential squared. Differentials in potential from one population to another are significant for problems of business, labor and economic planning.

These correlations and counter-correlations had better be regarded as only empirical, for the time being. A system of equations is under test which, if successful, will serve as a general rational interpretation of most of them. This system of explanation, in addition to using the concept of demographic gravitation, brings in the "human gas."

The gas analogy, or some equivalent concept, is necessary to explain the resistance of human beings to social gravitation. We know that there is a long-term drift of people toward the principal gravitational centers. Were it not for the expansive force of the human gas, representing the need of individuals for elbowroom, the center-seeking force of gravitation would eventually pile everyone up at one place.

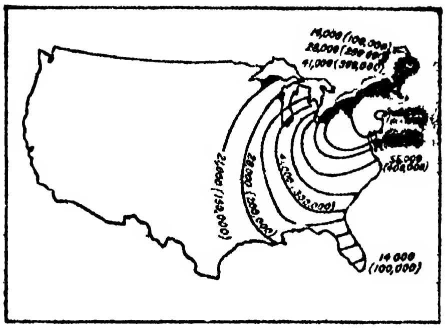
Once a potential map has been made, the total demographic energy of all the people with respect to one another can be computed. To compute the demographic energy of a nation, the population of each area is multiplied by the potential there, and half the sum of all these products is the total energy. We must divide by two to avoid counting the same energy twice; for example, to compute the mutual demographic energy of New York and Chicago at both places would be a duplication. The unit of energy is formed by two average Americans one mile apart. There are so many possible pairs among the 140 million people that the total Pp/d sums to hundreds of billions.

The trend of applications of Pp/d to social activities suggests that economic wealth is related to demographic energy. Direct evidence to support this hypothesis can be found in the income and census figures for the past century. The annual income of the United States increased from one billion dollars in 1829 to nearly 69 billions in 1939. During the same period the nation's "demographic energy" rose from decade to decade in about the same proportion—from 300 billion units in 1829 to 25,000 billion in 1939. If we divide the total income in any year by the number of units of demographic energy, the income per unit of energy comes to an average of a quarter of a cent. In other words, two average Americans one mile apart create by their free mutual relations an average of 0.25 of a cent per year. This ratio fluctuates with the boom-and-bust phases of the business cycle, reflecting the effects of inflation and deflation. The present annual income is estimated at 200 billion dollars and the demographic energy at 30,000 billion units, which indicates that the income per unit is 0.67 of a cent and that the present cheapening of the dollar is the greatest on record.

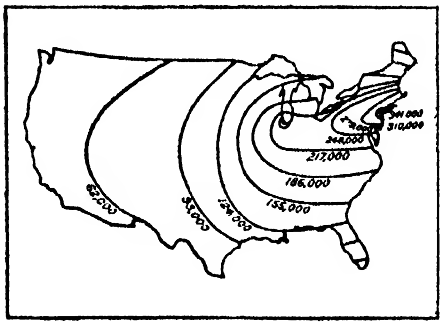
It is an attractive hypothesis to assume that Pp/d is a measure of the number of effective human relations between a group of P people and another group of p people who are d miles away. If each person in the P group is paired with each one in the p group, the number of pairings is P x p. It is common sense to assume that distance reduces the number of effective relations between the two groups, and evidence of many sorts indicates that the factor 1/d takes care of this. So demographic energy tentatively may be interpreted as a measure of human relations—leaving exactly what we mean by that to be defined by further observational tests.

Perhaps the crass materialism of this treatment of human beings can be relieved by taking to heart Leibnitz's philosophy of the monads. The monads, you will remember, are units of life which are characterized by possession of a soul. They do not push one another about as molecules do, but act through inner sympathy. When social physics advances to the quantum level, it may appear that the separating effect of distance is only external and statistical, and that one person can come into contact with another through impulses which make nothing of space and perhaps nothing of time also.

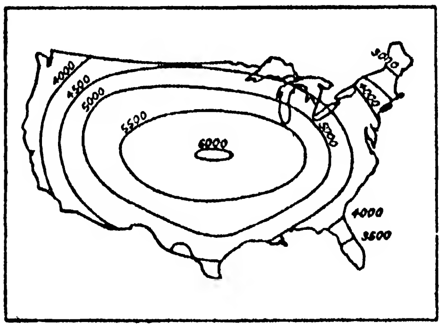
John Q. Stewart is associate professor of astronomical physics at Princeton University.



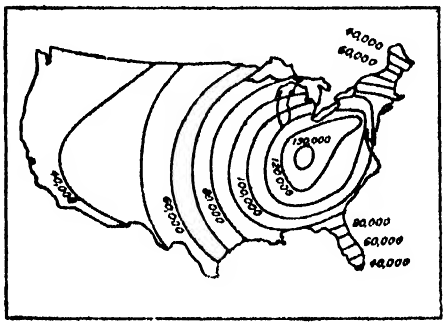
1840 POTENTIAL, compared in parentheses with 1930 potential, shows potential relationships change very little with population growth.



1900 POTENTIAL is shifted westward. The potential numbers on this page are larger than those on opposite page because units are smaller.



UNIFORM DENSITY of population would cause potentials to center in Kansas, illustrating how demographic and actual geographic centers differ.



RURAL POTENTIAL, *i.e.*, that outside of incorporated places, is less centered on New York. Peak potential is near Cincinnati and Louisville.

DISSECTED CORPSE in one of Jan Stephan van Calcar's woodcuts for Vesalius' *Fabrica* is hung by a rope passing through the eye sockets and around the base of the skull. On the wall at upper right is the diaphragm.

VESALIUS: DISCOVERER OF THE HUMAN BODY

His great De Humani Corporis Fabrica, which founded modern anatomy, is also an unsurpassed work of scientific art

by Martin Gumpert

ON July 17, 1903, in Baltimore, young Harvey Cushing received the following post card from the Isle of Guernsey: "I have bagged two 1543 *Fabricas!* 'Tis not a work to be left on the shelves of a bookseller." The card was signed by the great physician William Osler. A week later came another message: "Besides the two '43 *Fabricas* I have just ordered a third. We cannot have too many copies in America & no medical library is complete without one."

By autumn the three copies had grown to six, among them an imperfect first edition discovered in a Rome blacksmith's shop by another of Cushing's peripatetic friends. When Osler returned to Baltimore, the two bibliophiles spread their loot on his dining room table. It was a solemn and happy moment. From the obscurity that sometimes attends greatness, the two friends had retrieved six first editions of a treatise which Osler called "the greatest medical work ever printed."

Osler distributed his precious volumes to medical libraries with missionary enthusiasm. For Cushing, the moment in Osler's dining room was the beginning of a lifelong labor of love. His copy of the *Fabrica* grew into the world's most complete collection of works by its author, Andreas Vesalius. It is now in the Historical Library of the School of Medicine at Yale University. Today one need not hunt abroad for a copy of the *Fabrica.* The New York Academy of Medicine has even sponsored the publication of a modern edition from the original Vesalius woodcuts.

This sixteenth century work, *De Humani Corporis Fabrica,* written by the founder of modern anatomy, is indeed one of the most daring, creative and beautiful adventures ever undertaken by the human spirit. No one who can be moved by genius should die without seeing it. For medical men, whose work so often leads to a final attitude of cynicism, it has the power to turn cynicism into enthusiasm

It is regrettable that all young doctors are not made familiar with the life and work of Vesalius. This, however, is an unhappy by-product of the fact that even the best medical schools neglect the teaching of medical history. The anatomy textbook of today is a medical Sears, Roebuck catalogue. The anatomy of Vesalius is a testament of passionate devotion to medicine. Any doctor who has made the acquaintance of this powerful book will be better prepared for the practice of medicine and its deep and dangerous beauty.

The *Fabrica* is more than a milestone in the history of medicine. It is a great work of creative art. Curiously, it is not notable for literary quality. "As a book," Cushing once observed, "the *Fabrica* has probably been more admired and less read than any publication of equal significance in the history of science." But its text, like the libretto of an opera, has become merely scaffolding for the great music of its illustrations.

These illustrations depict man's first clear and accurate knowledge of human anatomy. Even now, after four centuries, the *Fabrica's* drawings show the freshness and enthusiasm of original discovery. In its perfect unity of format, print, picture and scholarship, the *Fabrica* is comparable to the great creations of early religious literature. Indeed, its perfection could have been achieved only through a reverence for the exquisite architecture of the human body.

The book was the joint product of a scientist—one whom Cushing ranked with Hippocrates, Galen, Harvey and Lister among the five great discoverers in medicine—and an artist, Jan Stephan van Calcar. A pupil of Titian, Calcar drew the anatomical features which Vesalius laid bare.

Great books and great discoveries are always dangerous, and the *Fabrica* was no exception. It was as daring as the later heresies of Galileo. It radically revised concepts of the structure of the human body which men had been taught for centuries. In its precise identification of all the organs, it seemed to leave no room for the "seat of the soul"—a perilous omission. The fury of the attack launched against the *Fabrica* was not reduced by the circumstance that Vesalius was only 28 when it was published.

Vesalius was a Belgian, born in Brussels on December 31, 1514. He came of a long line of illustrious physicians. His great-grandfather was doctor to Maximilian I of Burgundy. Grandfather Eberhard wrote a commentary on a famous textbook by Rhazes, the renowned medieval Arab physician. Vesalius' father was apothecary to Emperor Charles V of the Holy Roman Empire.

Vesalius' interest in anatomy began early. As a boy he dissected mice, moles, cats and dogs. These experiences possibly are reflected in the drawings of fat little cherubs performing dissections which decorate the initial letters of the *Fabrica's* chapters. By the time he had begun his medical studies at the University of Louvain, and soon afterward in Paris, his interest had become a passion. He obtained his first skeleton by robbing a gibbet.

VESALIUS' ardor for dissection did not please his instructors. In the sixteenth century it was regarded as indecent for a professor to take a knife in his own hand for dissection. At lectures this odious task was performed by barber surgeons. Vesalius reported of his teacher Guenther von Andernach, known as Guinterius, that he never saw him with a knife in his hand except at the dinner table.

The earnest young scientist soon became impatient with his teachers. Instruction in anatomy consisted of lectures, an occasional glimpse of a butchered dog and an annual dissection of a human corpse by the rude, ignorant hands of the barbers. Never did he see a nerve, an artery, a vein; never did he dare to take a bone in his hand.

So Vesalius began his own independent study of anatomy. He prowled about Paris churchyards and places of execution for subjects. At the cemetery of St. Innocent and at Montfaucon, dumping ground for the bodies of criminals, he was a constant

visitor. Sometimes he fought with wild dogs for the corpses he dragged home to dissect in the quiet of his room. Soon he could recognize every bone with his eyes closed, just by touching it. His skill gained him the privilege of acting as the barber at demonstrations. While he was still a student at Louvain he shocked his teachers by conducting a demonstration in which he lectured and dissected at the same time. It was the first public dissection at the university in 18 years.

At 22, Vesalius escaped this barren environment for the stimulating intellectual atmosphere of Venice. In this period Venice was the focus of the Catholic revival. Amid contrasts of luxury and pestilence, culture and filth, the serenity of Greek theology and groans of hunger, the Renaissance was drawing to a close. Vesalius threw his useful talents into the crusade of brotherly love launched by Ignatius Loyola and his new order of Jesuits. He helped the Jesuits care for the dying, the prisoners and the lepers. He bled patients, set leeches to work and tested the wonderful healing powers of quinine, recently brought from Peru by sailors.

Presently, just before his 23rd birthday, Vesalius was appointed professor of surgery and anatomy at the University of Padua. Now he had the means to realize his great dream—to get on with the science of anatomy. He began at once to reorganize the system of instruction. One of his first ventures was a full-dress public dissection. From all over Europe, hundreds of physicians, philosophers and theologians came to see and hear his demonstration. It lasted for three weeks of all-day sessions. Vesalius dissected dogs and other animals, displayed sections of human anatomy and climaxed his lecture by exhibiting a complete human skeleton.

In the midst of the revolutionary sixteenth century, anatomy was still dominated by the second century Greek physician Galen. European medicine, emerging from the medieval spell of Arabian science, was on the crest of a surge of neo-Galenism. The revival, moreover, was led by two of Vesalius' old teachers—Guinterius and Jacobus Sylvius, the latter the most renowned medical lecturer in Europe. Vesalius himself, as he began his work at Padua, was still a loyal Galenist.

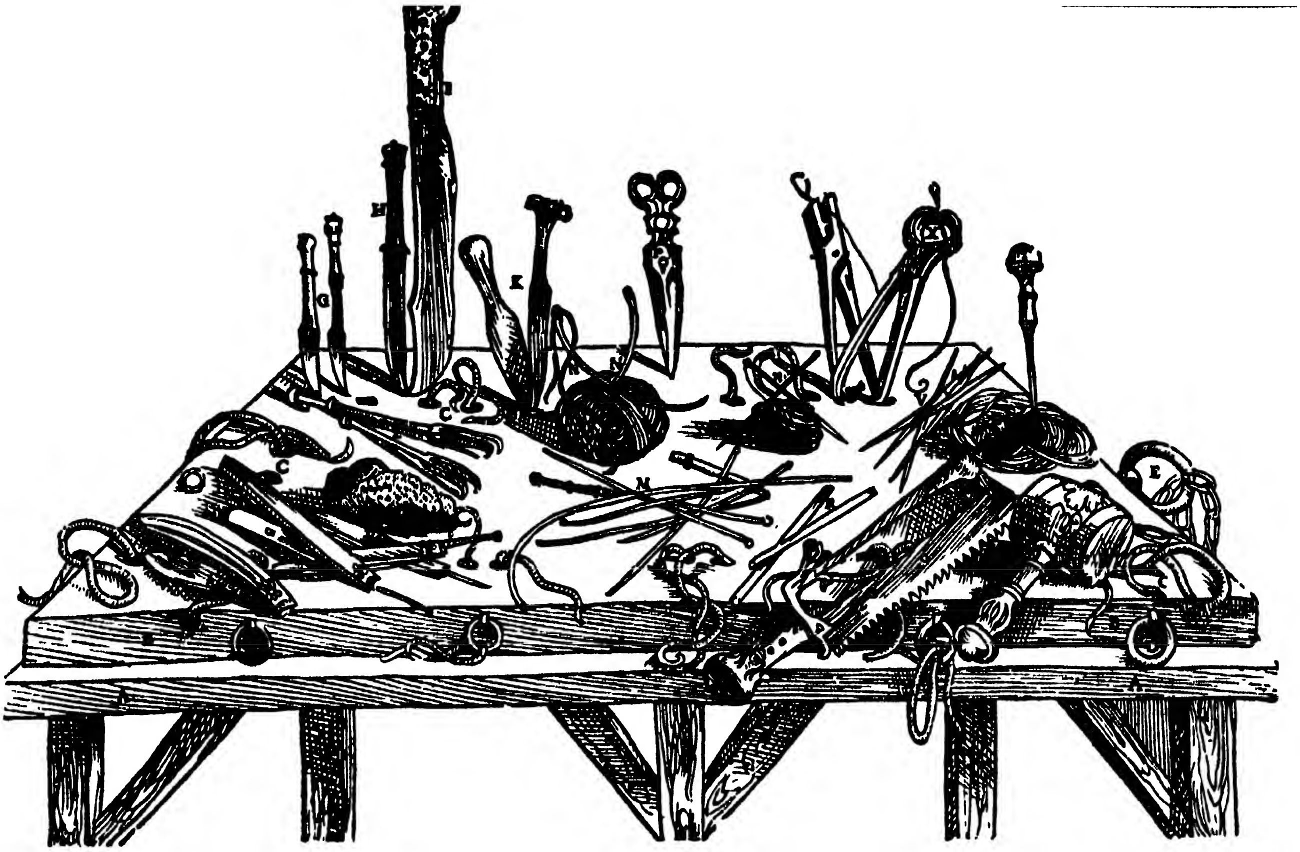
BUT already Vesalius had begun to discover errors which had been committed by the master. His dissections showed, for example, that the actual course of the azygos vein, running up through the diaphragm to the vena cava, was entirely different from Galen's description. As a result, Vesalius published a little treatise called *Letters on Vein-Cutting*, suggesting a new blood-letting procedure based on his discovery. This work was shortly followed by Vesalius' first anatomical publication, an outline of his lectures which he called *Tabulae Anatomicae*. It is fascinating to study these first anatomical sketches of Vesalius—three drawn by himself and three by Calcar. The correction of Galen's errors is already under way. But some glaring ones still remain: the liver is still shown with five lobes, the breastbone still has seven parts, the uterus is shaped like a bubble, the heart is inaccurately sketched, the pelvis is falsely situated.

Vesalius did not yet dare to challenge Galen's basic anatomy. He hunted assiduously but vainly for organs which Galen had mentioned. The *plexus mirabilis*, which Galen had described in minute detail, he could find in sheep but not in man. Then, in the year 1540, Vesalius was enlisted in a project which was to become the turning point of his studies. This was the translation of Galen's collected works into a magnificent new Latin edition. Vesalius edited the parts on the dissection of the nerves and blood vessels, especially one of Galen's most important works, *De Anatomicis Administrationibus*.

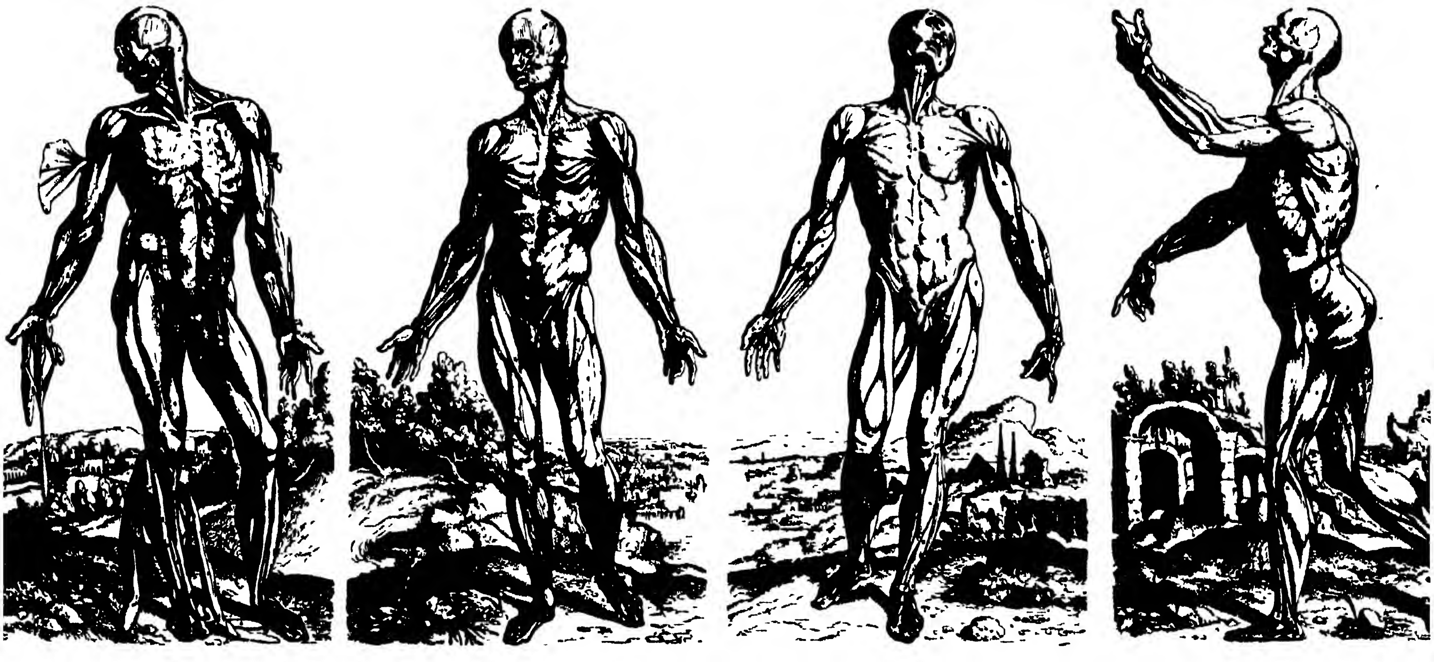
As he worked on this translation, Vesalius was delivering a course of lectures at Bologna, during which he reconstructed the skeletons of a man and a monkey. When the work was finished, he compared the two. In the monkey he found a lumbar vertebral process which was described in Galen's anatomy but which apparently did not exist in the human skeleton.

A great revelation dawned upon Vesalius. He realized, with sudden, shocking

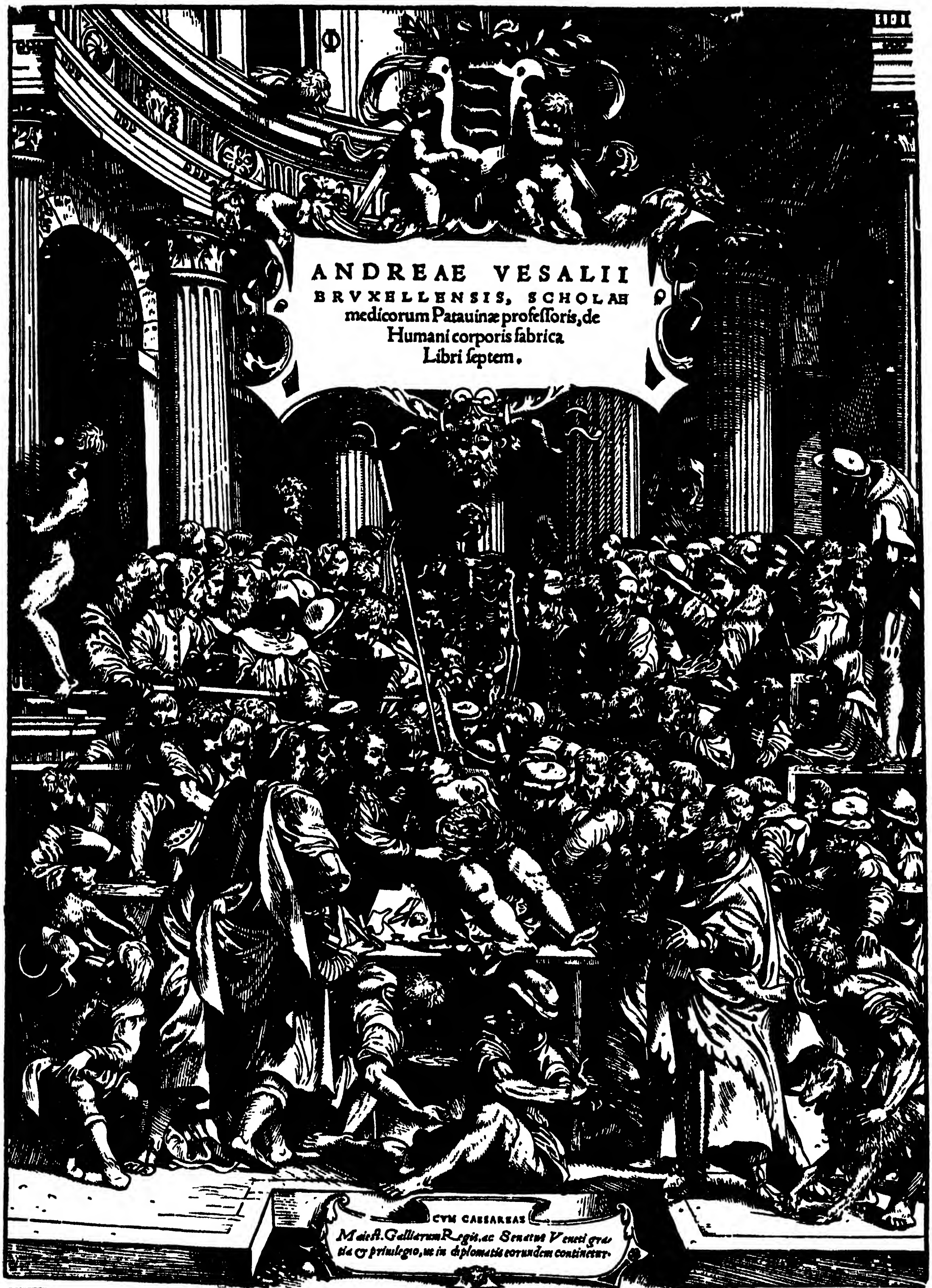
ANATOMICAL FIGURES make a monumental panorama when the *Fabrica's* folio pages are laid side by side. This series of eight tortured illustrations begins at the far right on the opposite page, proceeding through stages of dissection to the limp skeleton at the left. The illustrations are arranged in this order to show that Calcar placed his figures on an almost continuous landscape, identified as that of the Euganean Hills, near Padua. The figure at the far right shows the body from the side with the skin and some superficial tissue removed. Second from the right is the same figure from the front. The third figure shows the body with the mus-



THE ANATOMIST'S TOOLS were drawn by Calcar as they appeared on a table used by Vesalius to dissect living animals. Also on the table is a wooden slab fitted with holes and rings to fasten the ropes that held the animals motionless. The tools are various razors and knives (noted by Calcar with the letters F, G, H, I and K), hooks (L), styluses and a siphon (M), needles and stout bookbinding thread (N and n), a saw, a pair of scissors (P), a wooden mallet, reeds for inflating the lungs and other organs (R), copper wire for joining bones (S), pointed instruments for piercing bones (V), pincers for tying and cutting twine (X).



cles laid bare of superficial tissue. In the fourth figure several of the muscles, mainly those controlling the tibia and the fingers, have been laid back and left to hang down. In the fifth the muscles of the thigh and other parts have been cut away. In the sixth the head is thrown back and the lower jaw split in half. The seventh, which also appears on page 24, shows the body suspended by a rope with the viscera removed. The shoulder blade is also suspended lest, as Vesalius wrote, it fall down like a broken wing. In the eighth figure the breastbone and rib cartilages have been cut away and placed on the ground at left, leaving the skeleton almost stripped.



FABRICA'S FRONTISPIECE, discussed in the text of this article, is a symbol of the anatomical revolution begun by Vesalius. Here Vesalius stands by the cadaver performing the dissection himself. Before it had been done by barber surgeons. Calcar drew himself as the man with the book to the left of the seated skeleton.

perception, that Galen had never dissected the human body. Galen's anatomy was that of the ape! The obscure and erroneous details that had bothered him for years were cleared up at a stroke. His long, frustrating search for the imaginary organs mentioned by Galen was at an end. Vesalius' reaction to his astonishing discovery was characteristic: he was ashamed of himself. He wrote: "Ipse meam stupiditatem et nimiam in Galeni aliorumque Anatomicorum scriptis fidem haud satis demirari possum"—"I could not get over wondering at my own stupidity and overconfidence in Galen and the writings of the other anatomists."

THAT day in 1540 marked the birth of modern anatomy. Vesalius now went to work to present the first accurate description of the structure of the human body.

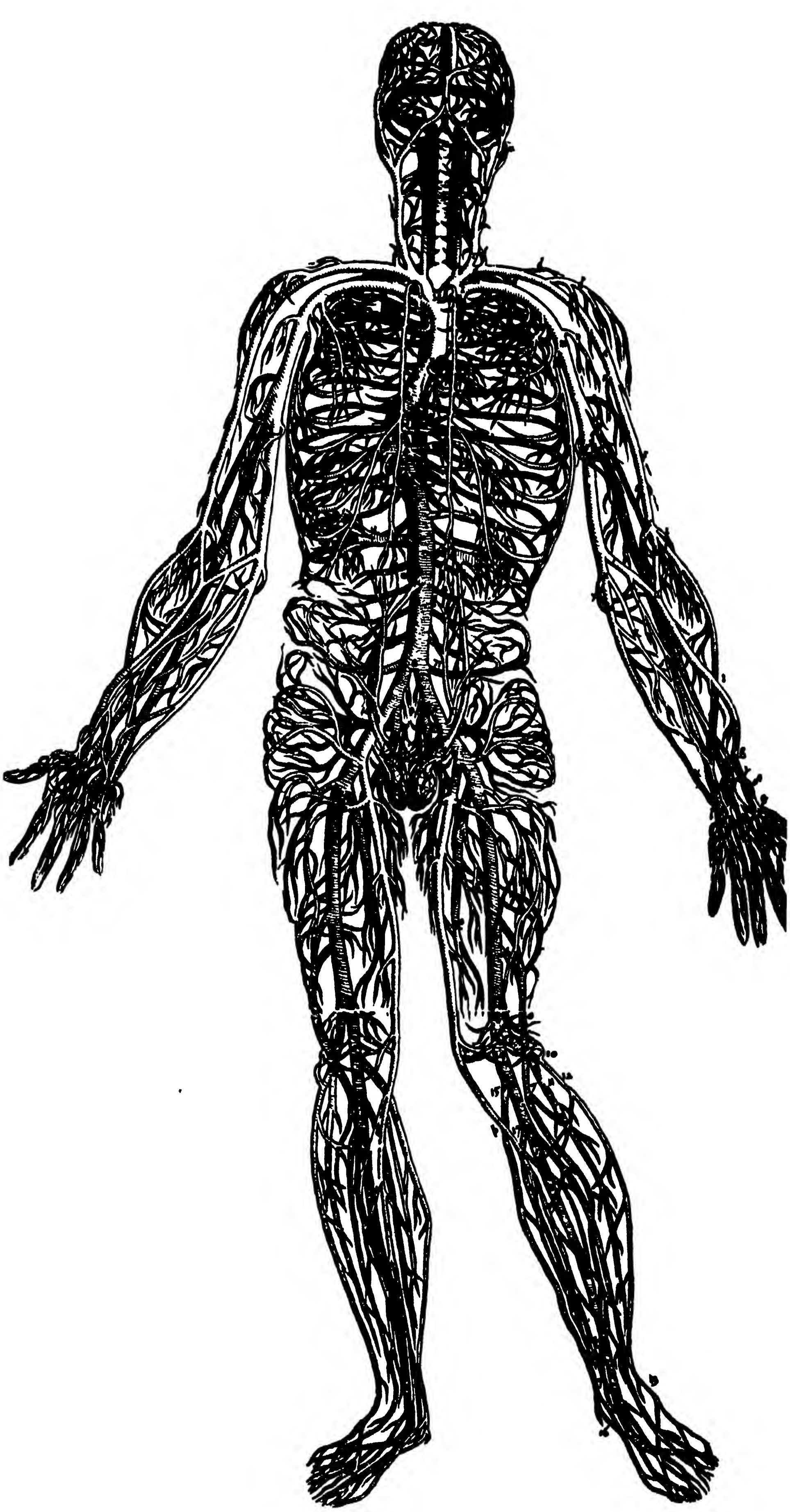
It took him only two years to complete the *Fabrica*. Meanwhile, he also undertook the dangerous task of removing Galen from his shrine in scientific opinion. His public dissections took on the character of turbulent mass meetings. He was greeted with both praise and bitterness as he destroyed the legend of Galen by citing more than 200 errors in his anatomy. "Thou, Galen," he declaimed, "who hast been betrayed by thine apes!"

On August 1, 1542 his work was finished. He took the huge manuscript to Venice and shipped it, with all the woodcuts and minutely detailed directions, to his publisher Oporinus in Basel. Vesalius soon followed to supervise the printing personally. But even while attending the birth of his masterpiece, he went on with his dissections. On May 12, 1543, a criminal named Jakob Karrer was beheaded. Vesalius promptly seized upon his body to perform the first dissection that had been witnessed in Basel in 12 years. For four centuries the skeleton Vesalius constructed from the bones has outlasted Jakob Karrer's misdeeds, whatever they were. Today it is still treasured by the Vesalianum in Basel as the oldest preserved anatomical specimen in the world.

In June of 1543 the great book finally appeared. Actually it was two books. Besides the exhaustive *Fabrica*, Latin and German editions of an *Epitome* were published for laymen. This was an outline of the new science and a safeguard against unauthorized condensations and translations.

In the woodcut which appears on the first page of the *Fabrica* one may see a portrait of Vesalius at 28—a bold, eager man with curly hair, piercing eyes, a high forehead, an upturned nose and a small birthmark over the right eyebrow. On the table before him are the flexor muscles of a cadaver's right forearm laid bare. Vesalius, grasping the hand, is supposedly exhibiting one of Galen's errors.

The frontispiece of the *Fabrica*, a panoramic view of Vesalius' dissection theater,



THE VENOUS SYSTEM is delicately traced in another of Calcar's woodcuts. Although Vesalius knew the existence of capillaries, he did not know the circulation of the blood. This was not discovered by Harvey until 1616.

boldly symbolizes his defiance of tradition and his devotion to science. At the center, Vesalius, scalpel in hand, stands beside a table upon which lies a woman's nude body with the viscera laid open. Every detail in the picture is a deliberate rebuke to the academicians. At the conventional medical lectures of the time the professor sat high on a kind of throne, reading a chapter from Galen. Below, the demonstrator, a physician, pointed with a wooden staff at the organs to which the reading referred. Even lower, in the pit of the theater, the barbers cut up the body, or rather, hacked at it with clumsy hands. In the *Fabrica* a skeleton occupies the throne of the professor, while Vesalius stands and lectures in the midst of his students. Underneath the table two squatting barbers disconsolately brandish their razors. Flanking the picture at the bottom are an ape and a dog—the rejected subjects of traditional dissections. At the left, braced against a column, is a naked figure which illustrates the play of living muscles. The bearded figure at the right, directing a servant to quiet the dog, is believed to be Realdus Colombo, Vesalius' assistant. At the top of the picture, upheld by naked little angels of anatomy, is Vesalius' family coat of arms—three fleeing weasels. And packing the theater to the doors is a throng of fascinated students, watching the dramatic event with the taut faces of men trembling with excitement.

The frontispiece falls short of being an artistic masterpiece, but it is a masterful illustration of Vesalius' place in the history of medicine. This is the birth of anatomy, firm foundation of the art of healing and of all scientific investigation of the human body.

THE principal illustrations of the *Fabrica* are its anatomical drawings, imprinted on folio pages by woodcuts. These fall into a narrative which unfolds like a great voyage of discovery. Calcar's massive figures are almost supernatural beings, each animated by an intellect. In attitudes of monumental suffering, their giant forms rise from a continuous landscape, identified as a section of Petrarch's countryside in the Euganean Hills near Padua. From page to page the giants shed their muscles like tall trees shedding their leaves in autumn, the landscape suffering with them. The narrative proceeds with the structure of great drama: in the final pages the figures stand on naked rock, stripped of every connection with life—poor remnants of humanity sinking on their knees, leaning against a wall or hung up by cords. From this has the study of anatomy sunk to a mere pedantic exercise!

The *Fabrica* was to revolutionize surgery and to found a new era of physiology from which was to grow the discipline of modern medicine. But it broke upon its time like the first nuclear chain reaction. Vesalius' old professor, Sylvius, called him a "madman," an unprincipled upstart who had disgraced his teaching. Guinterius turned against him. Even Vesalius' assistant, Colombo, a gifted but unscrupulous careerist, did his best to discredit him in his own stronghold of Padua.

Vesalius lacked the toughness that often accompanies genius. The attacks discouraged him. Within a year, during a fit of depression, he burned most of his notes and scientific papers and fled his university and his science. He began an entirely new life as court physician to Charles V in Madrid. He accompanied the emperor on military campaigns and to conferences

FABRICA'S ALLUSION to the legend of the Greek Poet Arion almost foretold manner of Vesalius' death.

throughout Europe. He also married Anna van Hamme, the daughter of a royal councillor in Brussels. In his bitter *Letter on China-Root* (quinine), which he wrote to a friend, he exclaimed: "Never again will I procure scientific material for myself and my pupils with such labor and danger as once I did in Paris, Louvain and Italy. In my youthful enthusiasm for science I endured this willingly and easily. Now I am through with the passion for writing." Vesalius was 31.

In 1556 his life took a minor turn. When Charles V gave his throne to his son Philip II, Vesalius entered Philip's service in Spain. This was probably the period when the portrait of Vesalius ascribed to Titian—now in Florence's Palazzo Pitti—was painted. It shows Vesalius with thinning hair and the high, pale forehead of a man growing old. A graying, slightly ruffled beard melts into the enormous breadth of his heavy body. His right hand holds a pair of spectacles. His left holds a book, an index finger between the pages. His wise, resigned eyes gaze past the beholder over some melancholy vista. It is Vesalius—without goals, lost in the darkness and corruption of the Spanish empire.

But the last spark had not quite been extinguished. While he was in Spain Vesalius received a book entitled *Observationes Anatomicae*, by Gabriele Falloppio, whose name is commemorated by the Fallopian tubes. Falloppio of Modena had been through an early career much like that of Vesalius. At 24 he was a professor in Ferrara, and he succeeded to Vesalius' chair in Padua after the treacherous Colombo resigned. In a clear, forthright script, every line of which breathed respect, Falloppio advised Vesalius of a few errors in the *Fabrica*, described the organs of hearing and gave an exact anatomy of the uterus, the ovaries and the clitoris.

For Vesalius, Falloppio's manuscript was a trumpet call. He read it in a fever of interest and in a few days wrote his last work, *Comment on Falloppio*. He sent the manuscript to Falloppio, but before it could be delivered Falloppio had died. Vesalius' book was published two years later in Venice.

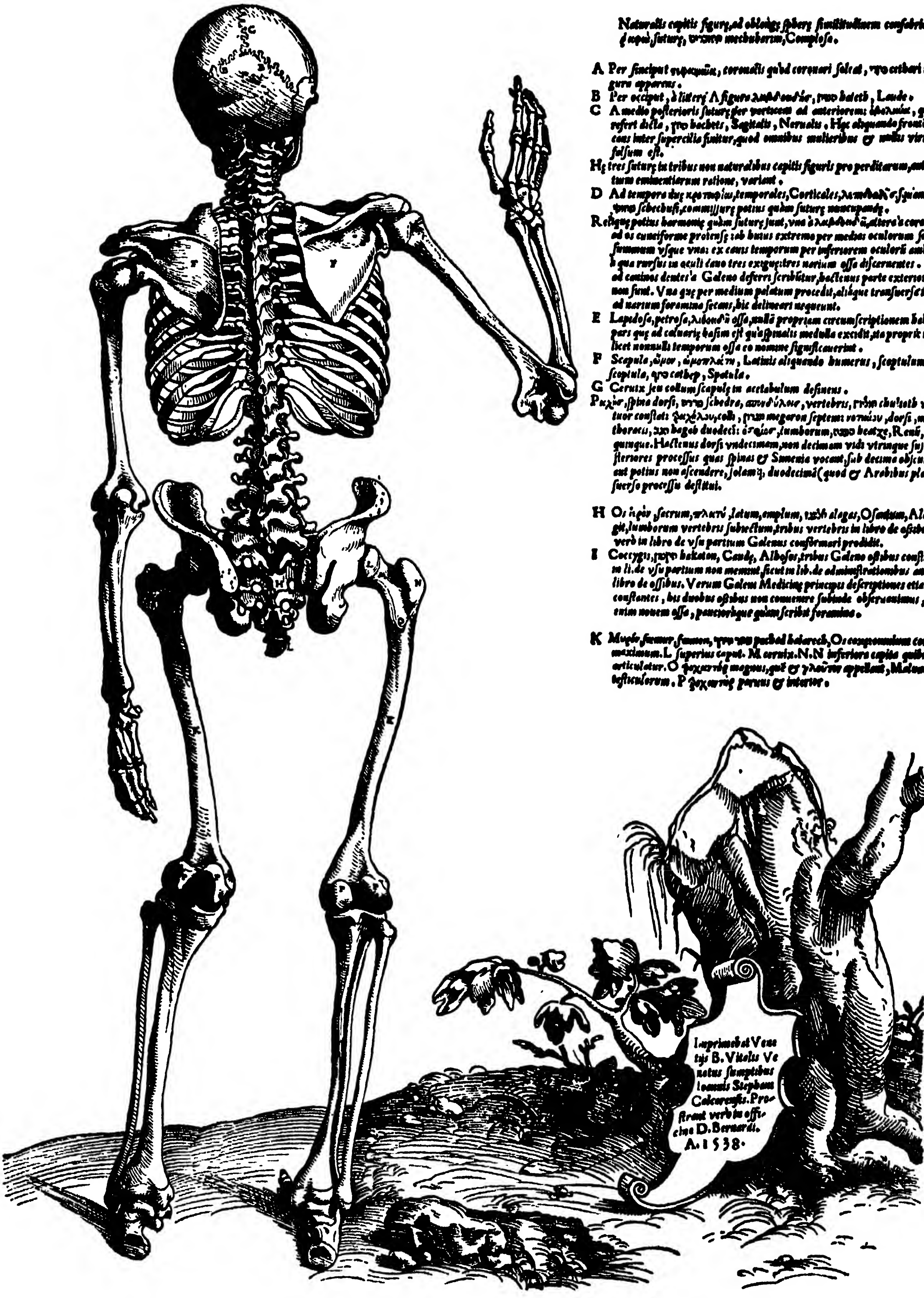
In the spring of 1564 Vesalius set out on a pilgrimage to Jerusalem, from which he was not to return alive. The reason for this journey and the circumstances of his death have never been completely clarified. According to a letter written by a Paris physician in 1565, Vesalius had a distinguished patient in Spain who died of an unknown sickness. "When he believed him dead," wrote the Parisian, "he asked the relatives for permission to perform an autopsy. This was granted, but when he opened the chest, the heart was still beating. The relatives accused Vesalius of manslaughter and Godlessness before the Inquisition. Since the killing was proved, the Inquisition wanted to sentence him to death. Only with difficulty was the king able to free him from great danger. Finally he was released on condition that for the expiation of his crime he should go on a pilgrimage to Jerusalem and Mount Sinai."

On Vesalius' return journey from Jerusalem, according to another report, his ship was wrecked on Zante, one of the Ionian Islands to the west of Greece. There he lay dying, untouched by the inhabitants because they thought he was a victim of the plague. Shortly before he died he was found on the beach by a visiting Venetian goldsmith. There, at 50, Vesalius was buried in an unmarked grave.

If this account may be accepted, there is a strange parallel between the end of Vesalius and the end of his great book. On the last page of the *Fabrica* is a concluding illustration, said to have been chosen by Vesalius himself. It is a picture of Arion, the poet and musician of Lesbos, who during a voyage was robbed and driven into the sea by Corinthian sailors. Vesalius had almost predicted his own death, and had chosen his monument

Martin Gumpert is a practicing physician and a writer on medical subjects.

ΣΚΕΛΕΤΟΝ A TERGO DELINEATVM.



Naturalis capitis figurę, ad oblongę sphęrę similitudinem confabricatę, ῥαφαὶ, suturę, [illegible] mechuberim, Compląsę.

A Per sinciput [illegible], coronalis quòd coronari soleat, [illegible] cethari: in alio figura apparens.

B Per occiput, à literę Λ figura λαμβδοειδὴς, [illegible] bateth, Laude.

C A medio posterioris suturę per verticem ad anteriorem: ὀβελιαία, quòd telum refert dicta, [illegible] bachets, Sagitalis, Nerualis. Hęc aliquando frontē ipsam secans inter supercilia finitur, quod omnibus mulieribus & nullis viris accidere, falsum est.

Hę tres suturę in tribus non naturalibus capitis figuris pro perditarum, aut remanentium eminentiarum ratione, variant.

D Ad tempora duę κροταφίαι, temporales, Corticales, λεπιδοειδεῖς, squamaeformes, [illegible] schecbusi, commissurę potius quàm suturę nuncupandę.

Reliquę potius harmonię quàm suturę sunt, vna à λαμβδοειδεῖ, altera à coronali vtrinque ad os cuneiforme protensę: ob huius extremo per medias oculorum sedes ad nasi summum vsque vna: ex cauis temporum per inferiorem oculorū ambitum vna, à qua rursus in oculi cauo tres exiguę: tres narium ossa discernentes. Quę verò ad caninos dentes à Galeno deferri scribūtur, hactenus parte exteriori mihi visę non sunt. Vna quę per medium palatum procedit, aliáque transuersę idem palatū ad narium foramina secans, hic delineari nequeunt.

E Lapidosa, petrosa, λιθοειδῆ ossa, nullā propriam circumscriptionem habent, sed illa pars quę ad caluarię basim est quà spinalis medulla excidit, ita propriè nominaturę licet nonnulli temporum ossa eo nomine significauerint.

F Scapula, ὦμον, ὠμοπλάτη, Latinis aliquando humerus, scoptulum opertum, scopula, [illegible] cathep, Spatula.

G Ceruix seu collum scapulę in acetabulum desinens.

Ῥαχίς, spina dorsi, [illegible] schedra, σπόνδυλοι, vertebris, [illegible] chulioth viginti quatuor constat: τραχήλου, colli, [illegible] megaron septem: νωτιαίου, dorsi, metaphrem, thoracis, [illegible] hageb duodeci: ὀσφύος, lumborum, [illegible] heatze, Renū, Alchatim quinque. Hactenus dorsi vndecimam, non decimam vidi vtrinque suscipi, & posteriores processus quas spinas & Sunenia vocant, sub decima obscurè admodū, aut potius non ascendere, solamq́, duodecimā (quod & Arabibus placuit) transuerso processu destitui.

H Os ἱερὸν, sacrum, πλατύ, latum, amplum, [illegible] alagas, Osaduum, Alchatis, Hagit, lumborum vertebris subiectum, tribus vertebris in libro de ossibus, quatuor verò in libro de vsu partium Galenus conformari prodidit.

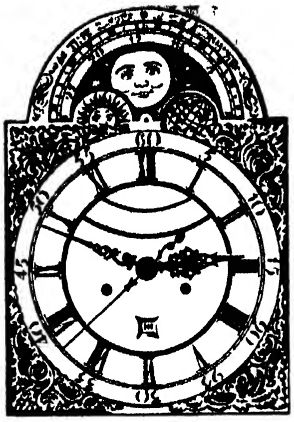
I Coccygis, [illegible] hakaton, Caudę, Albosus, tribus Galeno ossibus constituitur, cius in li. de vsu partium non meminit, sicut in lib. de administrationibus anatomicis & libro de ossibus. Verum Galeni Medicinę principis descriptiones etiam parū sibi constantes, his duobus ossibus non conuenire subinde obseruauimus, reperimus enim nouem ossa, pauciorąque quàm scribit foramina.

K Μηρὸς, femur, femen, [illegible] pachad haiarech, Os corporis omnium corporis ossiū maximum. L superius caput. M ceruix. N.N inferiora capita quibus tibię dearticulatur. O τροχαντὴρ magnus, quē & γλουτὸν appellant, Malum granatum testiculorum. P τροχαντὴρ paruus & interior.

CAVTVM EST DECRETO PAV. III. PONT. MAX. ET SACRATISSIMAE CAESAREAE MAIESTATIS Illustrissimique Sena. Vene. ne quis has Andreę Vesalii Bruxellensis tabulas aut imprimat, aut alibi excusas diuendat, sub pęnis grauissimis in priuilegiis expressis.

EARLY WORK OF VESALIUS was a lesser book called *Tabulae Sex*, also illustrated by Calcar. As indicated by the scroll on the stump at the right, this was printed in 1538, two years before the publication of the *Fabrica*

SCIENCE



Science Foundation

A NATIONAL Science Foundation seems likely to be enacted this month. A new bill resolving the disagreements which blocked the establishment of the Foundation last summer has been introduced in both houses of Congress with bipartisan sponsorship.

The bill is designed to meet the objections that impelled President Truman to veto last year's measure. The new bill, like the old, places control of the Foundation in a governing board of 24 members, who are to elect an executive committee of nine. But the Foundation's program of research contracts, grants, fellowships and scholarships will be administered by a director appointed by the President instead of by the Foundation committee. This was the feature of last year's bill to which the President objected most strongly.

There are three other important changes in the bill: 1) it replaces the proposed defense division with a military liaison committee, so the Foundation will undertake military research only at the request of the armed services; 2) it omits the previous plan for a committee to coordinate U. S. Government science activities, since the President has already set up such a committee independently; 3) it permits the Foundation board to create whatever divisions it chooses, instead of restricting it to a specified list. The bill specifically directs the Foundation, however, to form "for as long as [it] may deem necessary" commissions for research in cancer, poliomyelitis and degenerative disorders.

Research Budget

A RECORD sum for research and development will be appropriated in the Federal budget for the fiscal year ending June 30, 1949. Although the final figure will not be determined until June, it appears that the appropriation will be more than $900 million- -$150 million more than in the current year. New defense bills calling for additional military research may raise the total still higher.

The budget includes $15 million for the National Science Foundation's first year of operation. Some two thirds of the total is for Army, Navy and Air Force research and for the military projects of the Atomic Energy Commission. The armed services are to receive $550 million, of which $40 million is for the Office of Naval Research, whose contracts support much basic research. The total allotment to the Atomic Energy Commission is $118 million, two fifths of which is for laboratory construction.

Virtually all government departments will receive increased appropriations. Their tentative research budgets, in millions of dollars, are: Department of Agriculture, 56; National Advisory Committee for Aeronautics, 48; Bureau of Mines, 22; Geological Survey, 16; Bureau of Standards, 8.25; other Department of Commerce, 7.5; Public Health Service, 32.7; Tennessee Valley Authority, 5.

Synthetic Fuel

EXPERIMENTS looking toward the establishment of a synthetic liquid fuel industry have been given a boost by Congress. Because of the developing oil shortage, the Bureau of Mines has had a large-scale synthetic fuel research and development program under way for three years. The O'Mahoney-Case law, passed in March, extends this program for three more. It also authorizes the Bureau to build a demonstration plant for converting coal to liquid fuel by the German-originated Fischer-Tropsch process.

This plant will be built at Louisiana, Mo., by mid-1949. It will react coal with steam and oxygen to produce carbon monoxide and hydrogen, which in turn will be converted into liquid fuel.

Other processes also are under test. The Bureau of Mines has one plant in operation and a second under construction. The first, at Rifle, Colo., is producing 50 barrels of bunker oil a day from shale. The second, which will be near Louisiana, Mo., is to produce liquid fuel by the Bergius process for the hydrogenation of coal.

Atomic Energy

THE question of civilian *v.* military control of atomic energy is again in dispute. Several weeks ago Senator Kenneth S. Wherry of Nebraska introduced a bill to transfer functions of the Atomic Energy Commission to the Department of the Army. When Army Secretary Kenneth C. Royall disapproved the bill, it was laid aside. Another bill before Congress would authorize Senate members of the Joint Congressional Committee on Atomic Energy to order investigation of future nominees to the AEC by the Federal Bureau of Investigation. Although some doubt its constitutionality on the

AND THE CITIZEN

ground that it permits legislative interference in an executive department (in this case the FBI), the bill is expected to pass.

Health

THE National Health Assembly meets in Washington early this month to consider the nation's health and the prospects of an unusually large crop of health bills that have been introduced in Congress. The prospects of the bills are doubtful. One that seems likely to pass is a measure creating a National Heart Institute in the Public Health Service. The others, all of which appear unlikely of enactment, are: the Wagner-Murray health insurance bill; the Taft bill for grants to states in behalf of the "medically indigent"; the Saltonstall-Cordon bill for rural public health units; the Lodge bill to supply drugs, X-rays and diagnostic tests free to "such persons as may require them"; and a dental research bill.

The World Health Organization, having obtained ratification by more than the necessary majority of United Nations members (26), came into permanent existence last month. The United States is not yet a ratifier or participant. The Senate approved the WHO charter last year, but ratification has been tabled indefinitely by the House Rules Committee.

U. S. participation in WHO would consist chiefly of cosponsorship of research and educational projects and a contribution to its annual budget. Since the expected U. S. contribution in the first year, $2 million, represented one third of WHO's total budget, U. S. nonparticipation will require a curtailment of the organization's program. But few doubt that the U. S. will eventually join the organization.

UNESCO in the Field

BESIDES launching the Hylean Amazon Institute *(see page 11)*, UNESCO's Natural Sciences Division soon will open a new Field Cooperation Office, the fourth of its kind. Last year it established field offices in Cairo, Nanking and Rio de Janeiro whose purpose is to funnel scientific information into technologically backward areas. The fourth, to be in operation by the end of this year, will be in New Delhi.

This year will also see the start of work on the No. 1 project of UNESCO's Social Sciences Division: a study of tensions affecting international understanding. The study is the largest of its kind ever undertaken. Arrangements for American sections of the investigation were made at the February meeting of the U. S. National Commission, liaison body between UNESCO and U. S. scholars.

"Physics Today"

A NEW magazine covering the entire field of physics in a nontechnical manner appeared this month. *Physics Today*, edited by David A. Katcher, is published by the American Institute of Physics. Its basic circulation is the Institute's 8,500 members, but it is intended also for non-physicists who are interested in the subject.

Biological Institute

AN American Institute of Biological Sciences has been organized to serve as a clearing house for activities in biology. It will perform the same function in that field as the American Institute of Physics in the physical sciences. Formed with the assistance of the National Research Council, it already has 12 other societies as members: The American Physiological Society, American Society for Horticultural Science, American Society of Parasitologists, American Society of Plant Physiologists, American Society of Zoologists, Botanical Society of America, Genetics Society of America, Limnological Society of America, Mycological Society of America, Poultry Science Association, Society for the Study of Development and Growth, and Society of American Bacteriologists.

International Congresses

SCIENTISTS traveling abroad this summer will find more international scientific meetings in session than at any time since before the war. Besides the World Health Assembly in Geneva, the European schedule includes:

In London: International Rubber Technology Conference, June 23-25; Tropical and Subtropical Soils Conference, June or July (date not available at press time); International Congress on Mental Health, August 11-21.

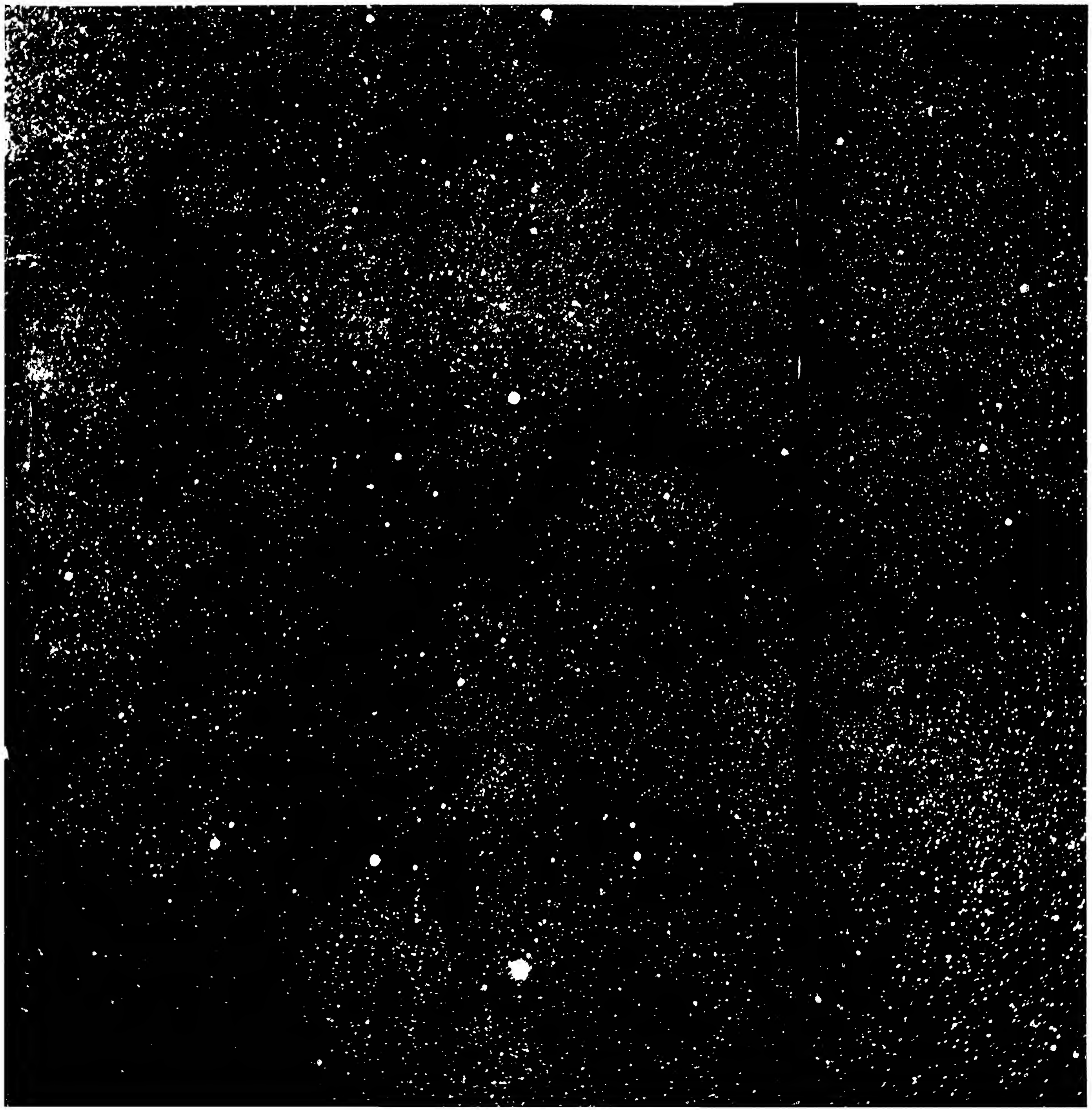
In Stockholm: Eighth International Genetics Congress, July 7-14; Society for Radio Technique and International Consultative Committee for Radio Telephony, July 12-31; International Association of Entomologists, August 9.

Meetings in June

SOCIETY of Automotive Engineers. Summer meeting. French Lick Springs, Indiana, June 6-11.

American Medical Association. Annual meeting. Chicago, June 21-25.

American Physical Society. Sectional meetings. Madison, Wis., June 21-23. Pasadena, Calif., June 24-26.



THE DUST CLOUD HYPOTHESIS

The vast distances of interstellar space are filled with huge amounts of dust and gas, the study of which has led to a new theory accounting for the origin of stars and planets

by Fred L. Whipple

IF the earth should disappear some day in a chain-reacting cloud of dust, a possibility which is mentioned half seriously in these deranged times, philosophers on another planet might find a certain poetic symmetry in its birth and death. Recent astronomical studies have given us reason to surmise that the earth was born in a cloud of dust. This Dust Cloud Hypothesis, as it is called, suggests that planets and stars were originally formed from immense collections of submicroscopic particles floating in space. Although it is still being developed, the dust cloud hypothesis possesses a plausibility that other theories about the origin of planets and stars have lacked.

The beginnings of our physical universe are necessarily beclouded in the swirling mists of countless ages past. What cosmic process created the stars and planets? Are new ones still being formed? Or were all that now exist made in one fell swoop? And if so, when did that happen? Scientists are making progress in their study of these fascinating questions, although they still cannot answer them with certainty.

The study begins logically with the earth itself. The earth's present composition tells little about how it was formed. But like an oldster's brittle bones, the earth's crust does yield evidence of its age. This evidence consists of traces of the products of radioactive disintegration within the earth's oldest rocks. Over vast intervals of time, radioactive uranium and thorium in the rocks break down into other elements. In five billion years half of the atoms in a given amount of uranium disintegrate. The products of this disintegration are helium and a stable isotope of lead, both of which are trapped in uranium-bearing rocks. (Thorium disintegrates in the same way, but more slowly.) By careful measurement of these minute traces of helium and lead, the age of the rocks can be determined. In this way the English scientist F. A. Paneth has shown that the oldest earth rocks have existed much as they are today for some two billion years. So we may take it as well-established that the earth's crust solidified about two billion years ago.

How long the planet had been in existence before it solidified we do not know. There is strong astronomical evidence, however, that the entire universe in its present form is not much older than two billion years. The spiral nebulae—galaxies outside our own Milky Way, each of which is made up of hundreds of millions of stars—appear to be receding from us and from one another at speeds that increase in proportion to their dis-

EMPTY SPACE, according to the evidence of this photograph, is far from empty. It is shot through with masses of loose material. The photograph shows a region of the Milky Way north of the star Theta Ophiuchi, the bright object near the bottom. The original plate was made by the great observer Edward Emerson Barnard with his 10-inch Bruce refracting telescope. Barnard, who died in 1923, collected his photographs of dark markings in a catalogue. One of the most famous markings is Barnard 75, the S-shaped object above and to the left of Theta Ophiuchi. Below Barnard 75 is a string of small globular dust clouds, the significance of which is discussed in this article.

tance. If they have been expanding at the indicated rate throughout their history, about two billion years ago all of the known universe must have been concentrated near one point.

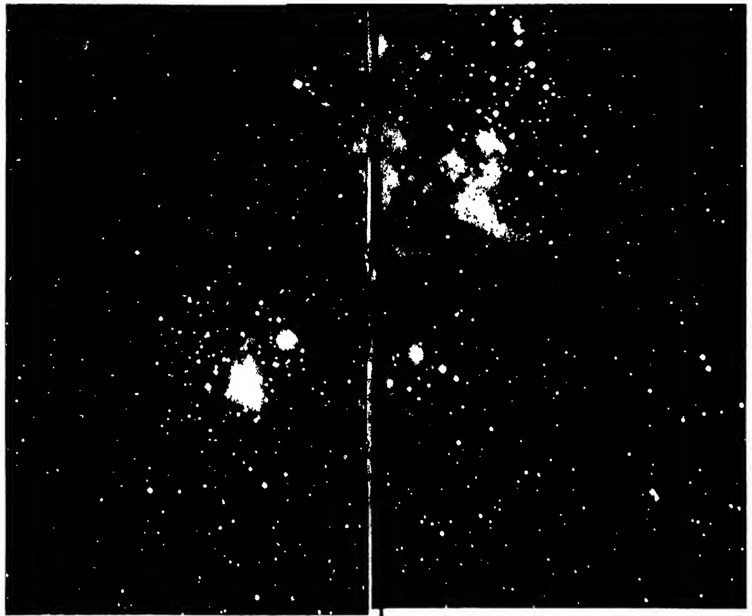
It is well to remember that this expansion concept may be wrong. Perhaps some fundamental error creeps into our calculations when we project our theories so far back in time from our present observations. We may be deceived in thinking that the universe is expanding. Perhaps we are observing some strange effect that space and time exert upon light rays which have been traveling for hundreds of millions of years.

In any case, our problem is to explain how the spinning sphere on which we live came into being some two billion years ago. Many possibilities have been explored. But one by one the old familiar theories have been shown by astronomers to possess weaknesses that make them implausible. The dust cloud theory also may be wrong, but it does seem to fit the facts as we know them better than the others.

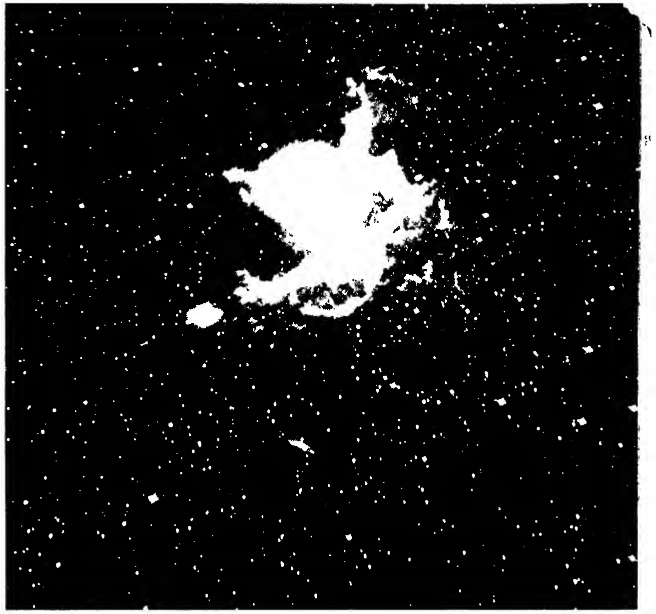
THE dust cloud theory begins with the fact that there are gigantic clouds of dust and gas in the abyss of space that lies between the stars. Observations by the world's astronomers during the past 20 years have proved the existence of these clouds. Interstellar space, formerly supposed to be empty, is now known to contain an astonishing amount of microscopic material. Jan Oort of the Netherlands, the present president of the International Astronomical Union, has calculated that the total mass of this interstellar dust and gas is as great as all the material in the stars themselves, including all possible planet systems. In other words, for every star there is an equal amount of dust and gas dispersed in space. The immensity of this quantity of material is beyond the grasp of human imagination. In the Milky Way alone, it comes to 300 million million earth masses. Yet interstellar space itself is so vast that this dust and gas is scattered more thinly than in the highest vacuum that can be created on earth.

We have a good deal of information about the composition of this nebulous star dust. The gases that we can detect are the ordinary elements with which we are familiar—hydrogen, helium, oxygen, nitrogen, carbon, and so on. Dutch astronomers have recently shown that these gas atoms slowly coalesce into chemical combinations and dust particles. While the structure of the dust particles is uncertain, it appears that most of them are very small—of the order of a fifty-thousandth of an inch in diameter. Evidence of their size and of the fact that they actually are dust particles is afforded by the way in which they scatter the light from distant stars. This scattering produces dark clouds on a photographic plate. The small amount of starlight that filters through these dust clouds is red-

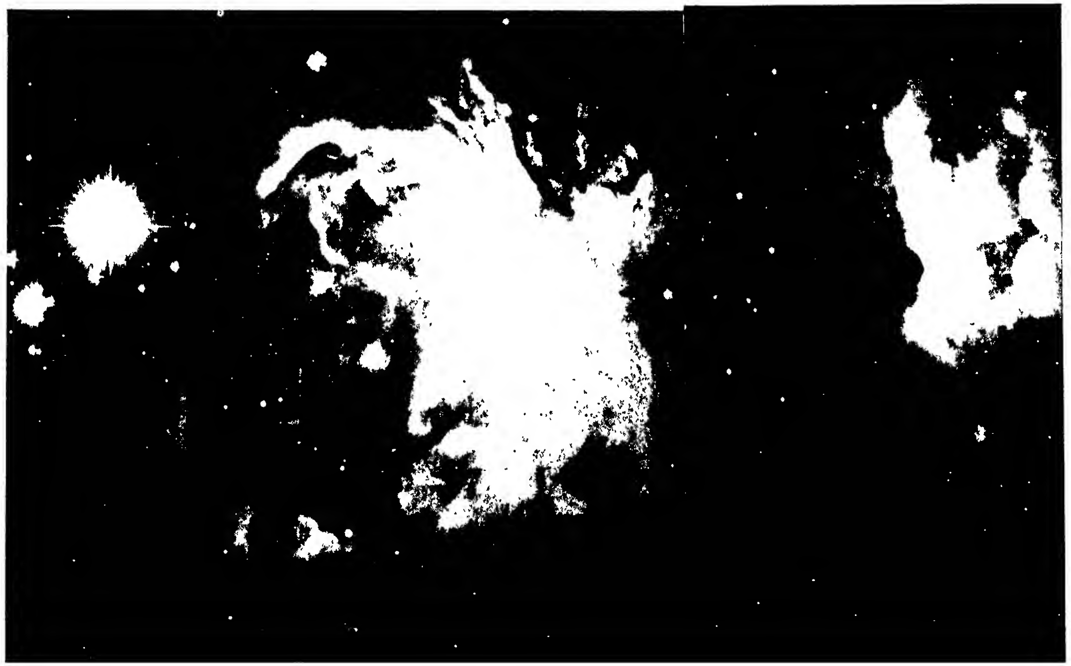
HORSEHEAD NEBULA in Orion is example of dense dust cloud. Photograph by 100-inch at Mount Wilson.



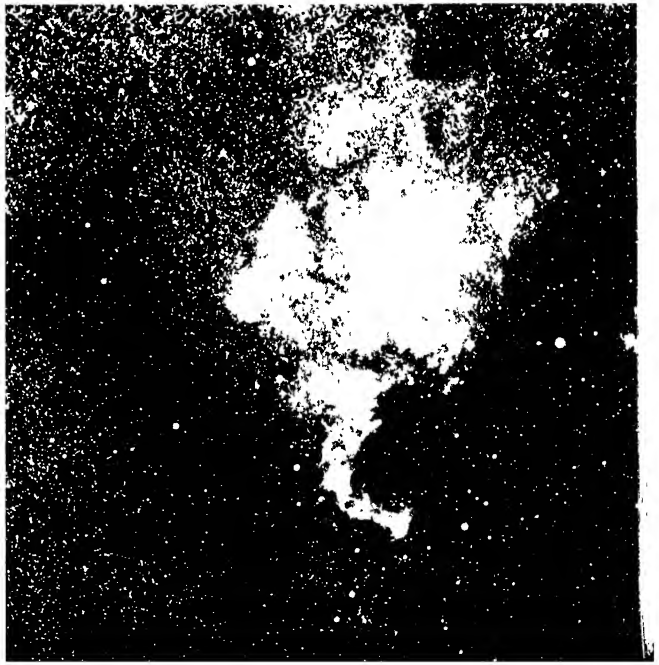
LIGHT AND DARK nebula in Carina, visible only from the Southern Hemisphere, shows how tiny dust clouds may be studied when they are projected against a luminous mass. Picture by 60-inch at Bloemfontein.



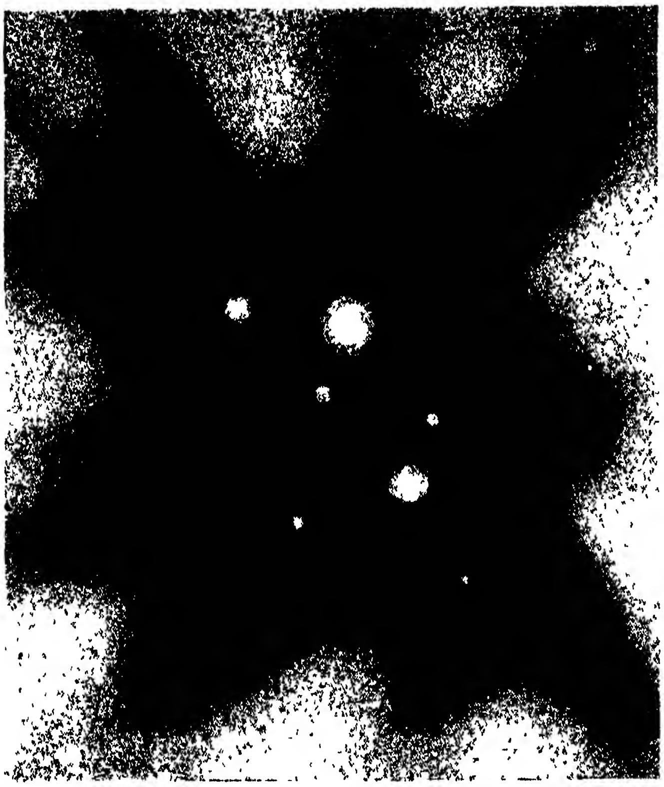
DIFFUSE NEBULOSITY about the star Auriga illustrates why dust clouds do not condense in the vicinity of a hot star. Light pressure literally blows the dust away. Photograph by 100-inch Mount Wilson reflecting telescope.



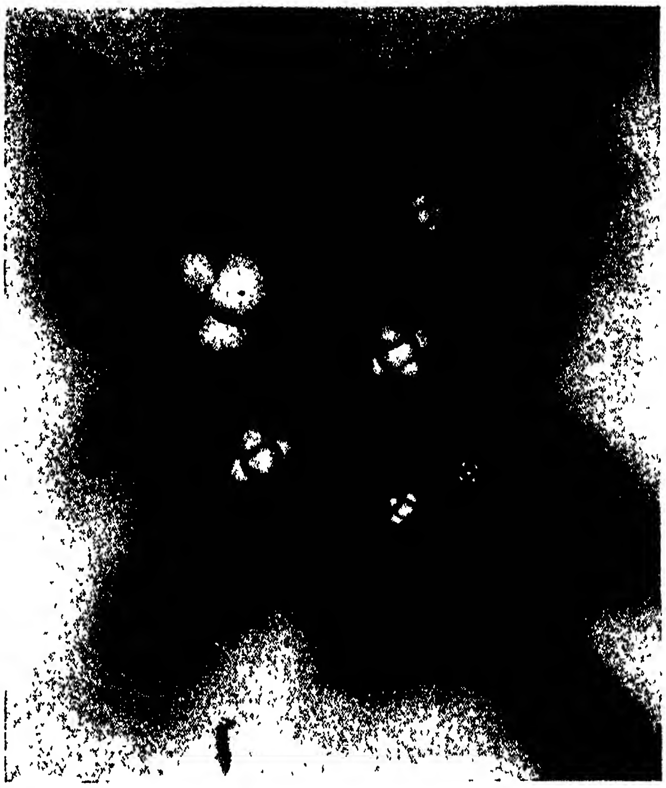
GREAT NEBULA in Orion demonstrates the huge winds of light pressure which blow through interstellar space. This nebula is a cloud which is apparently being scattered by radiation from several hot stars that are embedded in it. Photograph by N. U. Mayall and H. W. Babcock with the Crossley reflector, Lick Observatory.



NORTH AMERICAN nebula, named for its resemblance to the outline of the continent, shows vast quantity of the raw material from which smaller clouds may condense. Part of this nebula is bright, the rest is dark.



DUST CLOUD FORMATION begins with individual atoms floating in space. Absorbing quanta of light from the stars about them, the atoms are set in thermal motion. Here their closeness has been greatly exaggerated.



CHEMICAL COMBINATIONS of commoner elements is the next stage. When atoms of hydrogen, carbon and nitrogen collide, they form simple molecules such as cyanogen (CN), methane (CH_4) and ammonia (NH_3).

dened—for the same reason that the sun appears reddened during a dust storm: the long waves of red light are less scattered by small dust particles than are the shorter waves of other colors.

What collects these dust particles into clouds? Lyman Spitzer, formerly of Yale and now at Princeton, suggested that it might be the pressure of light. The pressure of light, which is so exceedingly small that it cannot ordinarily be observed, is strikingly demonstrated in comets' tails, which are formed by the pressure of sunlight forcing fine material away from the head of the comet.

THE writer, following the approach suggested by Spitzer, found that under rather unusual, but possible, circumstances the light from stars would tend to force interstellar dust into larger and larger clouds. The process is illustrated in the accompanying drawings. In the starlight of space, each dust particle casts a shadow. The shadow is minute. Nonetheless, it results in less light shining from the direction of one particle on another nearby, and vice versa. Hence the two particles tend to attract each other, by a force varying inversely as the square of the distance between them. The mathematics of this principle is similar to that of Newton's law of gravitation.

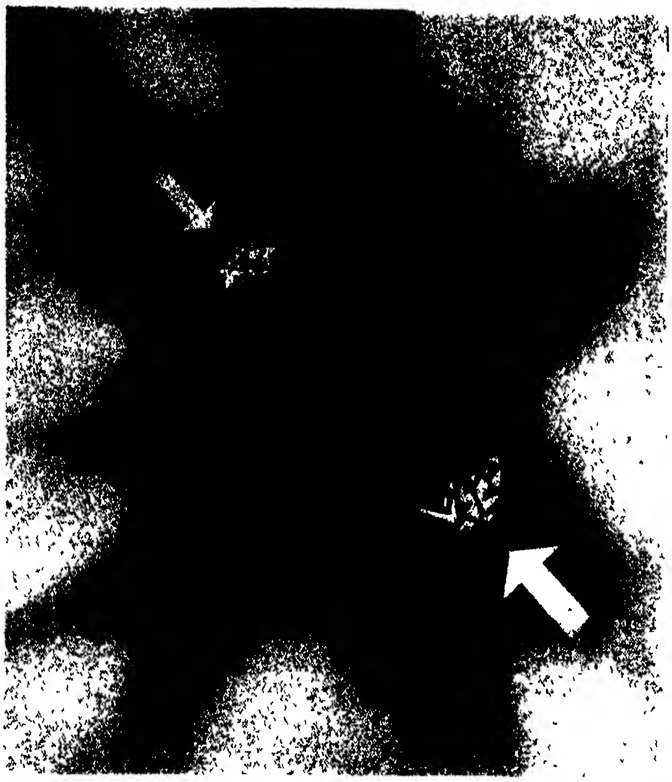
After a few particles are collected into a small cloud, the cloud casts a larger shadow in the starlight on the particles in its neighborhood. These particles are drawn into the cloud, making it larger and larger. If such a cloud is not too much stirred by its motion through other banks of dust and gas, and if too bright a star does not pass through it and scatter the particles by its light pressure, the cloud will continue to draw in dust. Finally it will attain a mass and density sufficient for gravity to become stronger than light pressure. The cloud will then begin to contract. Calculations show that for a dust cloud with the same mass of material as the sun, the two forces would be about equal when the diameter of the cloud was some 6,000 billion miles. This distance is 60,000 times the distance of the earth from the sun. It has been further calculated that such a cloud might develop and collapse into a star in less than a billion years.

These calculations were made before any dust clouds of this nature had actually been observed. During the war, Bart J. Bok of Harvard, while musing one day over some familiar photographs of the Milky Way, noticed some very small, round, dark patches that had not seemed important before. He studied a number of photographs of each region in the Milky Way and found the same dark patches in all the photographs. These were not photographic blemishes but truly dense, dark clouds in space! When Bok estimated their distances and calculated their diameters, he found that the smaller clouds in this group were about the same size as the hypothetical dust cloud for which gravity equals the light pressure on dust. Many were larger but few much smaller.

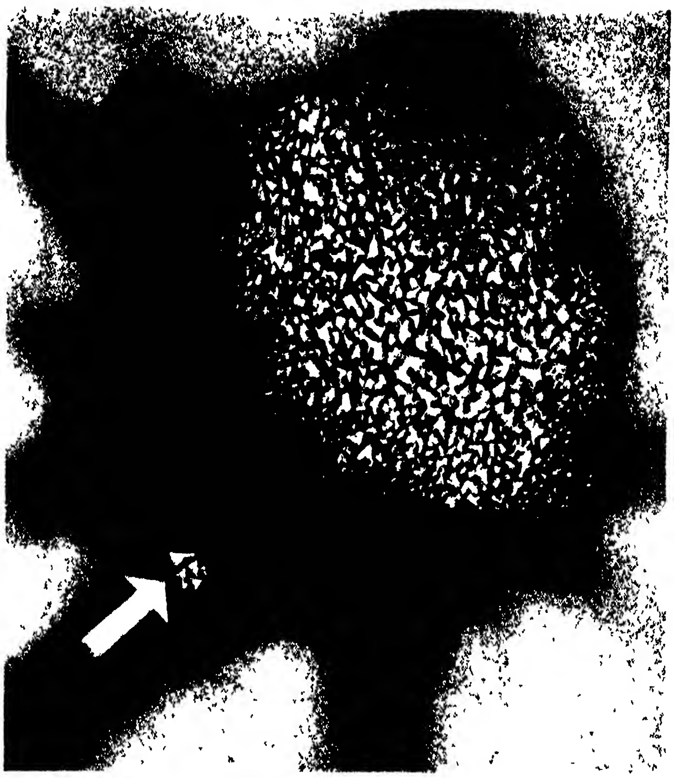
Bok's discovery suggested the fascinating possibility that the small dark clouds might be stars in the making. That new stars are constantly being formed from cosmic dust seems more than likely. There is no other reasonable explanation for the brightness of certain stars. A star's intensity of radiation, which shows how fast it is burning up its energy in nuclear reactions, indicates its maximum age. Some stars are so brilliant that they could not have radiated for two billion years, the minimum time we can allow since the "beginning." Hence they must have been born later than the solar system.

If we could measure the amount of matter in the Milky Way dust clouds, we might have a means of checking the dust cloud hypothesis and of estimating whether and when new stars are likely to be formed. Such measurements must depend on future observations, possibly with the new 200-inch telescope on Mount Palomar or other large instruments. The discovery of these clouds, however, encouraged the writer to study the possibility that not only a star but also a system of planets might condense out of such clouds.

LET us consider our solar system, therefore, as a case study of the formation of a star and its satellites. We have a huge dust cloud, as described above, which has begun to condense under gravity. There



DUST PARTICLES made up of many molecules are brought together by the gentle pressure of light from thousands of stars. Particles attract one another because light pressure in tiny shadow between them is low.



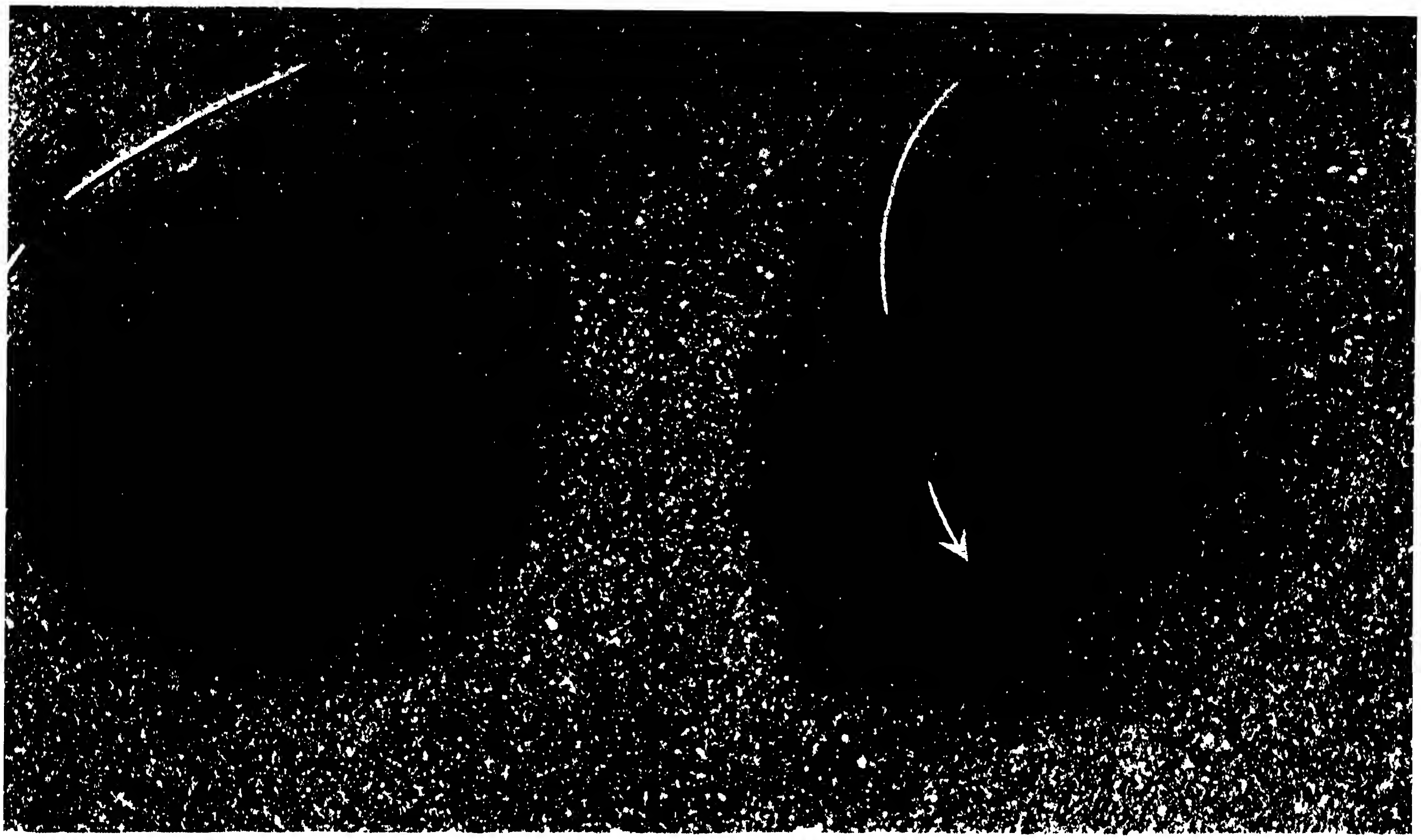
LIGHT PRESSURE also tends to propel individual particles towards larger aggregates. Thus dust clouds slowly grow bigger and bigger until they have sufficient mass for gravitational forces to take effect *(see next page)*.

will be minor turbulent motions of the material within it—sub-clouds, or streams of dust—that slide by each other or collide. But these motions cannot all be in the same direction. In order to explain the present slow rotation of our sun, we must assume that the motions of the streams in the original dust cloud canceled each other and that the cloud as a whole did not rotate. This point can be illustrated by a well-known parlor game. The victim is persuaded to sit on a piano stool with his arms outstretched and holding some books. The stool is started turning slowly. Its occupant is then instructed to draw in his arms and the books. He now spins so rapidly that he may fall off the stool. The same principle is illustrated by a whirling figure skater who speeds up her spin when she pulls in her outstretched arms. This phenomenon demonstrates the law of "conservation of angular momentum," or what might be called "rotational obstinacy." Angular momentum, or rotation around the center, may be variously distributed among the parts of the system, but the total momentum for the system as a whole remains constant. The principle applies in any system that is not acted upon from outside. All rotation that exists in the whole system in the beginning will remain there forever, and the rotation becomes more rapid if the system shrinks in size. Thus if the great dust cloud from which the sun was formed had had any appreciable rotation to begin with, after its collapse the condensed sun would have rotated with great speed. But actually our sun turns very slowly; it takes nearly a month to make a complete rotation. Consequently the original dust cloud must have been almost stationary.

This, by the way, would not necessarily be true of other dust clouds in our galactic system. The Milky Way itself rotates; hence we might expect many coalescing dust clouds within it to possess a great amount of rotation. In that case, according to our theory, they could not condense into single stars but would form double stars or even clusters. As a matter of fact, most stars *are* double or multiple, so that in this respect the dust cloud hypothesis is consistent with observations. The sun can be considered a somewhat unusual case.

Having accounted for the sun's slow rotation, let us go back to the original dust cloud. Under the force of its own gravity, it has begun to condense. At first it collapses very slowly, because the motions of its internal currents and streams resist its contraction. A group of moving particles is of course harder to collect and compress than one which is standing still. But in the course of millions of years the random motions of the streams within the cloud are damped out by collisions and friction. Meanwhile the cloud contracts more and more powerfully as it becomes smaller, because as its density increases, the force of gravity among the particles increases. The net result, with resistance diminishing and gravity increasing, is that the cloud collapses faster and faster. Its final collapse from a size equal to that of the solar system (*i.e.*, the diameter of the orbit of Pluto, the farthest known planet) would require just a few hundred years. Due to the increased pressure in the contracting cloud, its temperature rises enormously. In the last white-hot phase of its collapse, the sun would begin to radiate as a star. Its central temperature, due to contraction, would become great enough to start the cycle of nuclear reactions among carbon, hydrogen and helium which keeps the sun radiating, but no detailed theoretical study of this phase has yet been made.

NOW we must account for the evolution of the planets from the same great dust cloud. We return to the cloud before it has begun to shrink appreciably, and follow the largest stream in the cloud. If the dust in this stream is sufficiently dense, the stream condenses into minor clouds. They may be strung out in a series, as shown in the drawing on page 40. As these clouds drift along together, roughly in the same direction, they will pick up material less compact than themselves; hence they will grow slowly, feeding on portions of the great cloud. As they grow, the minor clouds, now "proto-planets," begin to spiral slowly in towards the center of the main cloud. They have gained in mass but not in angular momentum, so they move towards the center of gravity, somewhat as a whirling ball on a rubber string, if no force is exerted to keep it whirling,



HUGE DUST CLOUD, after formation by light pressure, begins to develop gravitational eddies. A small. dense cloud (*left*), moving at many miles a second, might have been pulled in by the larger cloud's mass.

PLUNGING INWARD, "proto-planets" in denser cloud are strung out by friction with dust in the larger cloud. At this point larger cloud would be some 60,000 astronomical units, or five and a half trillion miles in diameter.

SPIRALING toward the center of the cloud, the protoplanets are separated by various effects but still remain in the same plane. At this stage the entire dust cloud has also begun to contract at a much faster rate.

FINDING STABLE ORBITS, the planets circle within the collapsing cloud. Since the dust toward the center of the cloud is denser, each of the planets is spun in the same direction by picking up more dust on one side.

spirals in an ever-narrowing circle as its motion is slowed by friction. Some of the proto-planets move in more rapidly than others, their rate depending on their size and on chance encounters with other streams.

If the great cloud remained spread out forever, all the proto-planets would eventually wind up at its center. But long before some of them have completed their spiral, the main cloud collapses and forms the sun. Its rapid final collapse leaves a number of proto-planets stranded in their orbits, outside the collapsing cloud. Some are trapped too near the center and are pulled in or destroyed in the sun's heat. Others are far enough away to remain intact. They condense and become planets. Some of them may be at enormous distances from the sun. For all we know, there may be planets in our system beyond Pluto, the farthest one that we can see. Even a great planet like Jupiter, the largest in our group, would almost certainly have escaped discovery if it had been at a distance from the sun fifteen times that of Pluto. Pluto itself, which is about the earth's size, is barely within the range of probable discovery.

When first formed, the planets are hot, perhaps hot enough to be in a molten condition. But since they are relatively small, their heat of contraction is not sufficient to start the nuclear reactions that would make them radiate permanently like a star. Gradually they cool off.

We have described, then, how the dust cloud hypothesis accounts for the origin of the solar system. Now let us see how well our theory accounts for the system's peculiarities.

Any theory about the evolution of our planetary system must explain certain striking characteristics: 1) The planets all move in the same direction and very nearly in the same plane as the earth's orbit, called the plane of the ecliptic. 2) Their orbital paths around the sun are nearly circular. 3) Almost all the planets rotate, or spin, on their axes, in the same direction in which they revolve about the sun. 4) Most of them have moons or satellites—Jupiter has 11—which usually revolve about the planet in the plane of its rotation and in the same direction.

Thus the theory must account for a great deal of regularity in the system. But it must also explain some irregularities. For example, the orbit of Uranus and its system of five satellites, including probably the one recently discovered by G. P. Kuiper at the McDonald Observatory in Texas, is tipped up roughly at right angles to the plane of the ecliptic. Neptune's single satellite revolves backwards, as compared with the rest of the solar system, although Neptune itself turns in the forward direction and is thus properly oriented. Some of the satellites of Jupiter and Saturn also are contrary.

To begin with, the theory explains why the planets generally revolve in the same direction and in nearly the same plane. Their plane and direction are determined by the motion of the original stream from which they were created.

The planets' circular paths around the sun are accounted for by the spiraling phase of their evolution. Spiraling reduces the orbit of a revolving body more and more to the circular form. This principle can be demonstrated mathematically beyond question.

The spacing of the planets at their present distances from the sun is not explained by the dust cloud hypothesis. This spacing, as every astronomy student knows, follows a regular mathematical relationship known as Bode's Law. It is possible that the planets' distances from the sun were determined by gravitational effects over a long period of time rather than at the very beginning. The great mathematical astronomer Ernest W. Brown, of Yale, doubted that the planet distances could have remained constant for more than 100 million years or so.

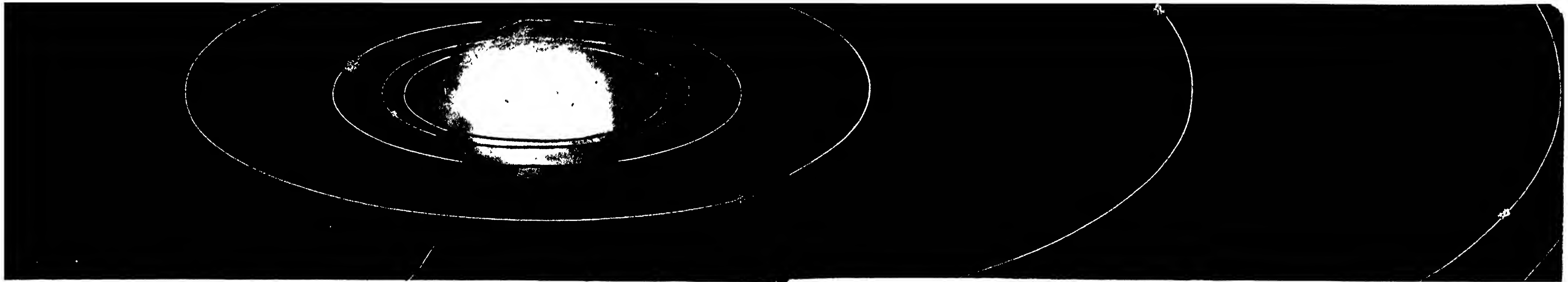
The planets' rotation or spinning is adequately explained by the dust cloud theory. As the great cloud condenses, it is denser towards the center than in its outer regions. Thus a proto-planet, when it spirals in, tends to pick up more material on the side that faces towards the center than on the side away from it. This process produces a result something like the rolling of a snowball. The side that picks up more material becomes heavier and is slowed up. The outer side of the planet, being lighter, travels faster and moves forward. Thus the process imparts a forward spin to the whole planet.

On the assumption that the planets actually gained all of their rotation in this fashion, we can estimate how large they must have been when they condensed. The size of a planet when it started to rotate can be calculated from its present speed of rotation and its mass. The results of these calculations are very encouraging to the dust cloud hypothesis, for the calculated diameter of each proto-planet figures out to about the same or a little more than the diameter of the orbit of that planet's farthest present satellite. This indicates that the satellites were formed while the planets were still distended as clouds. When a planet-cloud collapsed, the outer material collected into satellites or fell to the surface of the planet. Thus the satellites developed in just about the same way as the planets did when the sun-cloud collapsed.

Our theory that the satellites condensed from outer sections of the planet-cloud is further supported by the fact that, with one exception, every planet is very much more massive than all of its satellites combined. The exception is the earth-moon system; the earth weighs only about 82 times as much as the moon. The British astronomer Sir George Darwin suggested that the earth and moon really constitute a twin system, or "double planet," and that the moon was once much closer to the earth than it is today. In fact, the moon may actually have been in contact with part of the earth. The earth, during the early stages of its history, probably rotated so fast that its day was only four or five hours instead of 24. Then, according to Darwin's calculations, the friction of its tides slowly separated the moon from the earth and lengthened the day.

We have no difficulty in accounting for the rapid revolutions of the satellites around their planets. The planets themselves rotate rapidly. We would also expect the satellites to revolve in the same direction as their planets' rotation and in the plane of the equator. In most cases, as we have seen, they do. But what about the exceptions? Neptune's only satellite, the three outer ones of Jupiter and one of Saturn's revolve in a direction opposite from all the others and generally in planes different from those of their planets' equators. The answer is probably very simple: the maverick satellites were not a part of these planets' initial systems but were captured later, when they could no longer be completely controlled. Very likely there were originally many dense minor clouds, or potential planets, which did not develop into full-fledged planets. Some of these were small and outside the main stream. If a small cloud of this sort ran into a planet-cloud before the planet had collapsed, it would be captured and become a satellite. Normally the planet-cloud's rotation would carry the captured cloud along in the same direction, and would reduce the size of the satellite's orbit. But a satellite that was captured by a planet's gravity after the planet had collapsed would be less strongly influenced. If it was revolving backwards when it was captured, it would continue in a retrograde orbit, even though held a prisoner by the planet's force of gravity.

OUR hypothesis has another major irregularity to explain. Why are some of the planets so much larger than others, and why are the large planets so much less dense than the earth? The average density of Jupiter, for example, is only a little greater than that of water, while the earth is five and one-half times as dense as water. Saturn, if it could be put into a huge sea, would actually float. The explanation of these differences probably lies, as Henry Norris Russell of Princeton has suggested, in the fact that the giant planets were bigger to begin with. Their size gave them a huge gravitational attraction so that they could hold the light gases, such as hydrogen and helium, which would float away from a less massive planet. Their ability to attract and hold light elements would have a double result: they would grow rapidly, and they would be relatively light in proportion to their volume. On the other hand, a smaller proto-planet such as the



STAR FLARES UP when the heat and pressure at the center of the collapsing dust cloud are sufficient to set off a nuclear reaction. The central sun, however, is still surrounded by a fiery cloud of dust and gas. Here the solar system has been placed in this situation. Reading outward from the sun are the four inner planets: Mercury, Venus, the Earth and Mars. Beyond Mars there might have been two other planets which are now extinct, a possibility which is discussed in the caption below. After these come Jupiter, Saturn, Uranus, Neptune and Pluto. The dust cloud theory proposes that the orbits of the inner planets were inside the incandescent sun cloud. This might account for the fact that they have thinner atmospheres and fewer satellites than the outer planets. Most of their satellites and atmospheres might have boiled away in heat of the new sun.

earth, which has less ability to hold hydrogen or helium, would soon reach the limit of its growth. Lyman Spitzer has recently shown that hydrogen and helium are escaping from the earth's atmosphere even today. We have every reason to believe that hydrogen and helium are relatively more common in the universe as a whole than on the earth, they are much more abundant than oxygen, nitrogen, carbon and other elements which seem more prevalent to us. About one-third of the sun, for example, is hydrogen and it also contains a large amount of helium. Thus hydrogen and helium are major building blocks of the universe, and it is entirely possible that many of the other elements were made by nuclear synthesis from these two gases.

THERE is still another odd peculiarity of the solar system that the dust cloud hypothesis seems to explain quite well. This is the fact that the planets which are closest to the sun have relatively few satellites and comparatively thin atmospheres. The explanation is this. When the sun was collapsing to its final form, the energy released by its contraction made it hot. The inner planets—Mercury, Venus, the Earth and Mars—were then in a fairly dense region of the condensing sun. As a result, their atmospheres and surfaces were heated to very high temperatures. Most of their satellites would boil away. Fortunately for the theory, this boiling period was very short—perhaps a few months or years—else the planets would have boiled away also. As it was, the earth and moon probably were not entirely spared by this "bath of fire", both may have been appreciably reduced in size by the evaporation of their outer rocks. The outer planets, being outside this bath of fire, would not have been much affected, which accounts for the fact that they still have thick gaseous envelopes and a comparative abundance of satellites.

One other puzzling phenomenon, perhaps the most fascinating of all, remains to be explained. This is the great collection of asteroids, or minor planets, found in the region between Mars and Jupiter. There are at least 1,600 of these "flying mountains," ranging from a mile or two to three or four hundred miles in diameter. All revolve in the same forward direction and near the plane of the ecliptic, although not as close to it as the planets. Their grouping suggests that the asteroids had a common origin. Are they the building stones of a planet that was stillborn, or the debris of one that was smashed? Present opinion favors the latter possibility. The proof, though not yet complete, is fairly convincing. Harrison Brown at the University of Chicago and Carl Bauer at Harvard have recently shown that meteorites—pieces of interplanetary material that fall on the earth as shooting stars—must be fragments from a broken planet. Other studies by C. C. Wylie in Iowa indicate that these shooting stars or fire-balls swing about the sun in orbits resembling those of some asteroids. Though the chain of evidence at this point is weak, we may reasonably accept the tentative conclusion that meteorites are baby asteroids, and that the asteroids in turn, are broken pieces of a once completely formed planet. Harrison Brown calculates that the planet was about the size of Mars.

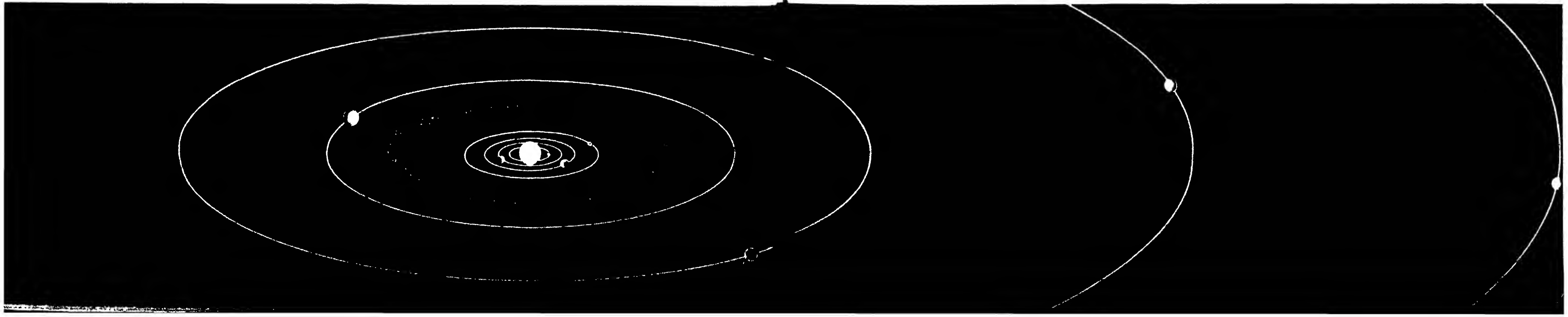
How was the planet smashed? Probably by collision with another planet; there may even have been more than two planets involved. On the dust cloud theory we can easily assume the formation of an eccentric planet which would cross the path of one in the main stream. If it did, sooner or later we would expect the two planets to collide. The resultant cosmic explosion would produce the scattered asteroids. (An explosive collision between one of the large asteroids and the earth, that might destroy a continent, is an ever-present possibility. The famous mile-wide crater in Arizona, and the tremendous explosion that flattened a forest in Siberia in 1908 are believed to have been caused by small asteroids.)

It is interesting to speculate about the possible effects that the asteroid planet's destruction may have had upon the earth. The collision must have occurred after the planets had cooled considerably. If it came within the period of geological history—that is, the last billion years—the effects on the weather of the planets must have been tremendous. After the explosion, interplanetary space would have been filled temporarily with a cloud of fine dust and gas. Contrary to what one might assume, this dust, though it obscured the sun, would not make the earth colder. A calculation by Donald H. Menzel of Harvard shows that if the earth were enveloped in an obscuring cloud, sunlight would be scattered or reflected by the cloud in such a way as to fall on the dark side of the earth as well as on the side facing the sun. Consequently the earth's nights would be much brighter and warmer. The long polar winters would be milder, and ice caps would melt. The result would be a great rise in the earth's average temperature. There is no geological proof of this theory, but it may explain certain phenomena that have puzzled geologists. It is conceivable, for example, that this process caused a prolonged heat wave that eliminated dinosaurs from the face of the earth.

WE have seen, then, that the dust cloud hypothesis accounts for a great many of the facts about our solar system. The chief difficulty in the theory has to do with the question of how the proto-planets maintained themselves during the early stages. At that period the dust clouds had to be very rare, their average density being more nearly a vacuum than the vacuum in a Thermos bottle. Yet they had to hold together sufficiently to pick up material from the rarer spaces between them and had to be massive enough to grow and to spiral in towards the sun. Such a situation is difficult to imagine, but there is some theoretical evidence that it is possible.

We must now consider whether the dust cloud theory is more convincing, or has fewer weaknesses, than other theories that have been proposed. The famous Nebular Hypothesis of the French mathematical

SOLAR SYSTEM TODAY is the reality which theories of its origin must explain. Its principal unifying characteristic is that the planets and their satellites, with a few exceptions, spin on their axes and rotate about the sun in the same direction and in the same plane. The dust cloud theory has been able to account for this better than previous theories. In this drawing another recent idea has been added to the dust cloud theory. This concerns the two extinct planets shown in the drawing above. Recent studies of meteorites have indicated that they and the asteroids are shattered fragments of one or more extinct planets. One possibility is that two planets between Mars and Jupiter collided to form what is now the asteroid belt. In this drawing the size of the planets has been exaggerated. Satellites, except for the rings of Saturn, have also been omitted.



astronomer, the Marquis Pierre Simon de Laplace, suggested that the sun and planets derived from a great revolving nebula, or cloud. In this respect Laplace's theory sounds somewhat like the present one. But he assumed that the planets were formed from rings of matter left behind when the dish-shaped nebula collapsed. The nebular hypothesis meets with the overwhelming difficulty that it requires that most of the solar system's rotation be carried by the sun. As we have seen, the slowly rotating sun actually contains only a small percentage of the system's total rotation or angular momentum, while Jupiter contains more than half. It is not possible to account for the observed motions by Laplace's theory.

ANOTHER famous and extremely important theory, known as the Planetary Hypothesis, was proposed by the geologist T. C. Chamberlin and the astronomer F. R. Moulton, of the University of Chicago, early in this century. They postulated that the planets were formed as the result of a near collision between the sun and another star. The star came very close to the sun, perhaps even grazing its surface. Huge tides were raised on the sun and great quantities of material were torn from it. This material is then supposed to have condensed into droplets which eventually coalesced into planets. The planetary hypothesis has many attractive features, and has dominated thinking in this field for many years.

One of its principal difficulties, which is also common to other theories that require a stellar collision or near-collision, was pointed out by Henry Norris Russell and proved by Lyman Spitzer. Let us consider the physical state of the hot, gaseous material which, according to this theory, is to be removed from beneath the surface of the sun very rapidly, say within an hour or two. While this gas remains in the sun, it is held by the sun's enormous gravity, some 28 times that of the earth. If it were not extremely hot, the gas would collapse into a very dense mass. It is kept distended by solar temperatures which range from 10,000 degrees F. at the surface to some 40 million degrees at the center. Suppose, then, that we scoop enough material out of the sun to make the planets, allowing for a considerable loss into space. We are drawing out gas at a temperature of perhaps 10 million degrees. At the instant when it is released from the sun's great gravity, the explosive pressure of this superheated gas is fantastically great. Released suddenly, the gas expands in an explosion of almost inconceivable force. Most of the gas is lost forever from the solar system. Furthermore, it is very difficult to conceive of a process whereby the remaining gas would cool and condense into droplets, or collect in masses as large as the planets.

Recently the German physicist C. F. von Weizsacker has developed a new

TINY DARK SPOTS made visible against a huge luminous nebula are possibly dust clouds at the beginning of their evolution into stars and planetary systems. The nebula is Messier 8, in the constellation of Sagittarius, the Archer. Photograph was made by the 60-inch reflecting telescope at Mount Wilson Observatory.

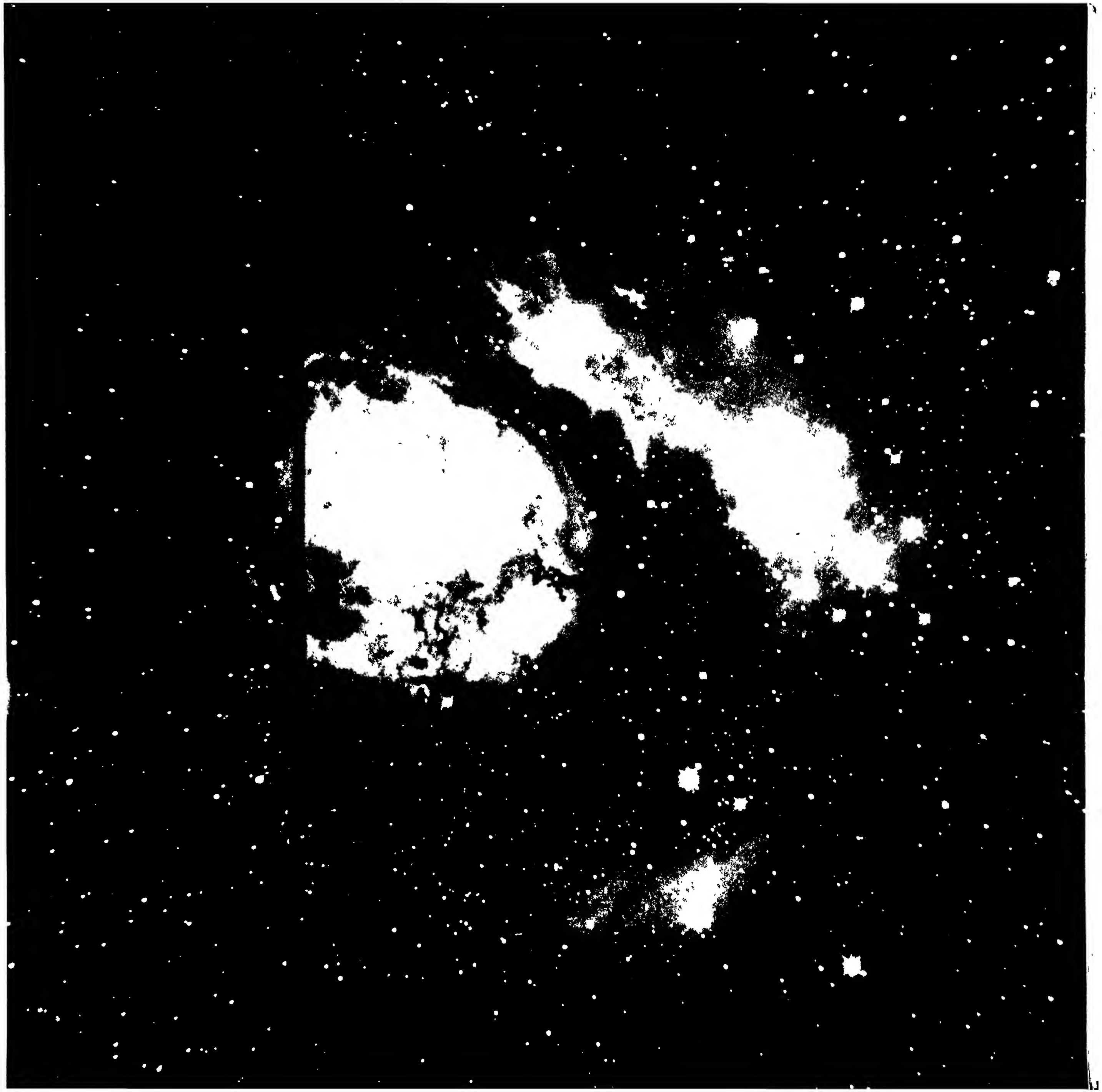
mathematical theory for the evolution of planets from a gas-and-dust cloud rotating about the sun. His theory can be made to predict the Bode's Law relationship of planet distances from the sun. There is still some question, however, whether the Weizsäcker theory really works. Moreover, it leaves wide open the question as to how the gas cloud came into existence and into motion about the sun. Whatever its value as an explanation of the origin of planets, Weizsäcker's theory is of great current interest to physicists and astronomers because of its wider applications in the theoretical study of large masses of gas.

All of the current theories about the birth of the stars and planets leave much to be desired. The evolution of the solar system remains foggy, which may be fitting, considering that the system may actually have been formed in a dusty fog. The truth is that we are still groping in the haze of a poorly illuminated and ancient past. Perhaps an entirely new advance in science will be required to light our way. On the other hand, it is possible that we have already stumbled on the correct path but cannot see clearly enough to recognize its worth.

In any case, the dust cloud hypothesis revives an old and intensely interesting speculation. Are there other living planets like ours? If the planets in our system developed from an encounter of the sun with another star, we should expect other planetary systems to be exceedingly rare, for the odds against such encounters are very high. But if the solar system developed at the "beginning of things" by some general but yet mysterious process, or later by condensation of dust clouds, other planetary systems are likely to be numerous. The dust cloud theory thus suggests a possibility that worlds with human or intelligent life may be fairly frequent throughout the universe.

The consideration of such questions no longer belongs only in the realm of "science fiction." If intelligent beings exist on other planets, we may some day establish radio contact with them. Conceivably we may be able to send ships into space to cruise among planetary systems belonging to other stars in our neighborhood. There our descendants may find strange types of intelligent beings—or at least settle the argument.

Fred L. Whipple is associate professor of astronomy at Harvard University.



LUMINESCENT LIFE is found among 40 orders of animals and two groups of plants. At the far left (1) is the hatchet fish, *Argyropelecus.* The herring (2) is not naturally luminous, but here illustrates a culture of luminescent bacteria which often grow on dead fish. *Linophryne arborifera* (3) has a thin luminescent tail and ventral fin. *Photoblepharon palpebratus* (4), a fish of the East Indian Banda Sea, harbors

THE LUMINESCENCE OF LIVING THINGS

The soft, cold light given off by a host of plants and animals is an engaging mystery, especially for writers and scientists. Herewith a biologist presents a brief essay on what is known of bioluminescence

by E. Newton Harvey

THE luminescence of living things has charmed and mystified mankind from earliest times. The phrase at once suggests the firefly and the glowworm, described by Aristotle and Pliny mentioned by writers on nature throughout recorded history, famed in song and poetry. Shakespeare wrote:

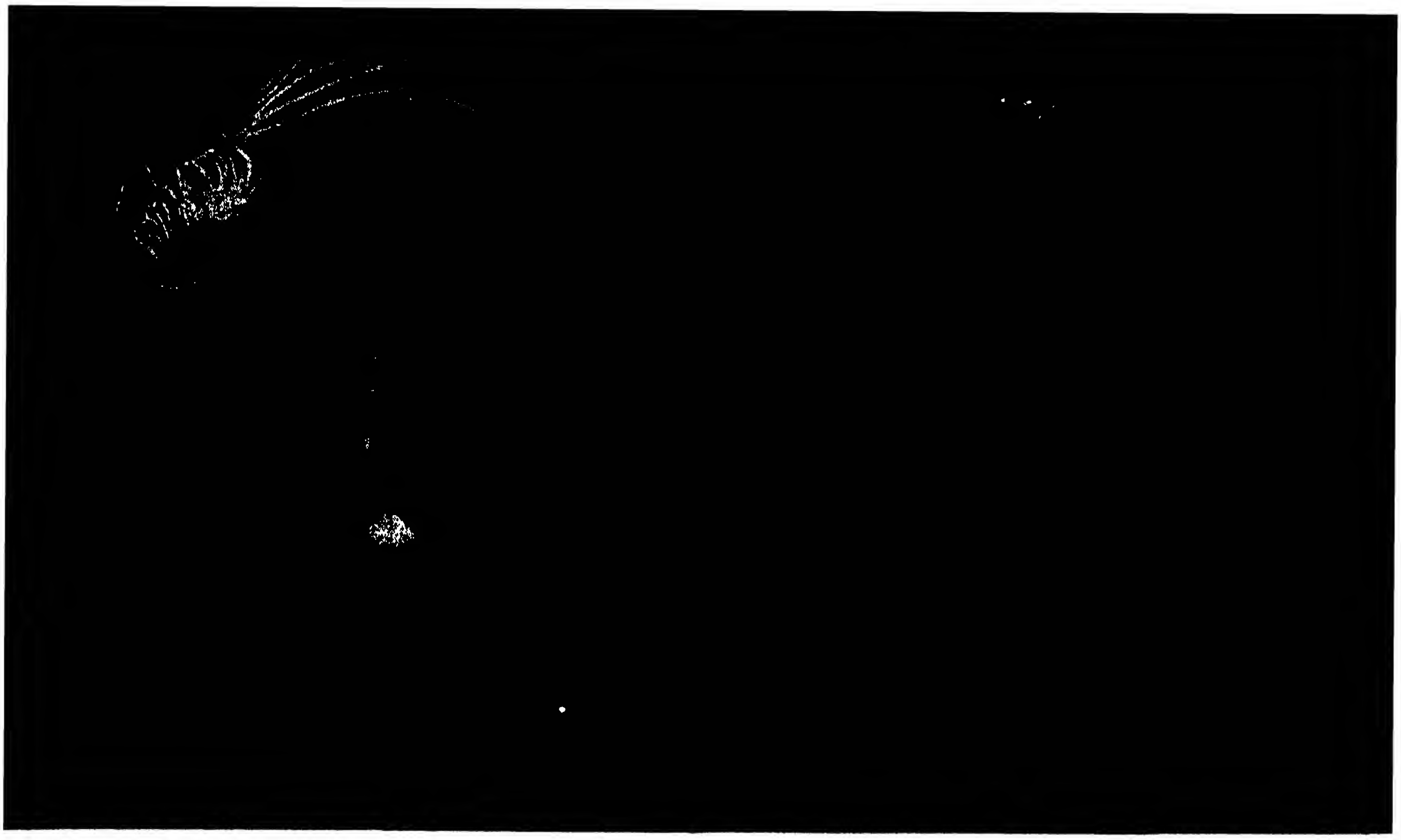
"Like a glowworm in the night,
The which hath fire in darkness,
none in light."

Who has not thrilled at the myriad sparkling lights to be observed on almost any night in late spring as, in the words of James Russell Lowell:

"The fireflies o'er the meadow
In pulses come and go"?

Here is not only a spectacle but a fascinating scientific problem. The firefly and the glowworm emit "cold light," as it is commonly called. How is it possible for a living thing to produce a light without at the same time producing heat?

This problem of bioluminescence is less of a mystery at present than it was 50 years ago. We are now accustomed to lighting houses and offices by a form of cold light: the fluorescent tube. One need merely touch the glass wall of a fluorescent lamp to realize that the light is actually cold. On the inner wall of the tube there is a thin layer of white powder. When it is "excited" by invisible ultra-



under each eye a culture of luminescent bacteria which it can turn on and off. *Acanthephyra purpurea* (5), a deep-sea shrimp, squirts a luminous fluid when it is frightened. *Photurus pennsylvanica* (6) is a species of firefly common to the U.S. *Omphalia flavida* (7), a luminescent leaf spot fungus, here grows on a coffee leaf. *Idiacanthus fasciola* (8) has a double row of luminescent spots which run the full length of its sinuous body.

violet radiation, generated by current passing through the tube, the powder fluoresces, that is, it absorbs the energy of the radiation and converts it into visible light with practically no loss as heat. This process, a very efficient one, is called a luminescence to distinguish it from an incandescence, in which the light is emitted as a result of high temperature—a very inefficient process.

Many different kinds of luminescence are known, classified according to the kind of energy that is converted into light. When the exciting energy is chemical, the process is called chemiluminescence. The problem is to find out what chemical is involved and the mechanism by which the chemical reaction takes place.

Although we may not always be able to isolate and purify the chemical compound concerned in a biological process, it can at least be given a name. Sometimes the name is "substance X" or "factor Q," sometimes A, B, C or D, as vitamins were named before their chemical constitution was known. In the case of the firefly, the light-emitting material is called luciferin, meaning "light-bearer."

We know that oxygen is necessary for light emission by the firefly. The luminescent process is an oxidation. In addition, like practically all biological processes, the luminous oxidation of luciferin proceeds only with the aid of an enzyme, in this case one called luciferase. Research in bioluminescence is concerned with the isolation and purification of luciferin and luciferase and with the complete series of reaction-steps, not only during the oxidation of luciferin, but also during its formation from some precursor in the luminous cells.

An important question immediately presents itself: What species of luminous animal is most favorable for chemical work? There is a large number to choose from. More than 40 orders of animals and two groups in the plant kingdom have developed the ability to luminesce. These vary from the simplest known organisms, the luminous bacteria, to so complicated a vertebrate as a deep-sea fish. For chemical study, by far the most valuable form is a marine crustacean less than an eighth of an inch long called Cypridina.

Curiously enough, all the 40 orders containing luminous species are either terrestrial (like fireflies and other insects; earthworms and myriapods) or marine (such as flagellates, jellyfish, sea pens, comb jellies, marine worms, crustacea, molluscs, squid, brittle stars and ascidians). No fresh-water luminous species has been found. The reason for this is still unknown.

BIOLUMINESCENCE is responsible for the phosphorescence of the sea, a phenomenon that not only amazed and mystified the older voyagers, but inspired some of the most flowery descriptions to be found in scientific literature. Like the firefly and the glowworm, phosphorescence of the sea has fascinated the poet, from the first century Roman poet Martial, who referred to the sparkling skin of women sea bathers, to Lord Byron's Corsair, one of whose characters:

> "Then to his boat with haughty gesture sprung.
> Flashed the dipt oars, and sparkling with the stroke,
> Around the waves phosphoric brightness broke."

Not until many years after the perfection of the microscope was it realized that all marine phosphorescence came from living animals, some of it from millions of minute protozoa entirely too small to be detected with the naked eye. These organisms glow intermittently when they are stimulated by breaking waves or other mechanical disturbance.

We cannot consider here each of the 40 groups of luminous organisms. A few have been of particular value for physicochemical study; others are of interest for the remarkable biological adaptations that they exemplify. Among luminous bacteria, for example, three distinct types are found: saprophytic, parasitic and symbiotic. The saprophytic type live on dead fish or meat in refrigerators, making the whole surface luminescent. This was the light that astonished Robert Boyle in 1672 and that in 1944 frightened a citizen of Mexia, Texas. Rushing into a police station, the latter exclaimed, "My meat,

EIGHT OTHER SPECIES begin with *Lycoteuthis diadema* (9), a deep-sea squid which squirts luminous fluid, as opposed to the dark fluid squirted by most squids. The comb jelly *Pleurobrachia* (10) is responsible for most of the larger flashes of luminescence seen in the sea at night. *Phillirrhoe bucephala* (11) is a luminous snail which has no shell. The pale round mouth, *Cyclothone braueri* (12), has a body which

it's all lit up!" This particular instance of "mystery meat," due to luminous bacteria, was widely reported in newspapers and magazines.

Robert Boyle tested the shining meat and also shining wood, whose light is due to threads of luminous fungus, in his air pump to see if the light would disappear when air was removed. He found that it did and thereby performed a crucial experiment showing that luminous bacteria (and fungi) require air (meaning oxygen) for luminescence. Boyle did not know that the light was due to luminous bacteria or that oxygen was the necessary gas withdrawn by his pump. Nevertheless he deserves much credit for the first important work on bioluminescence.

WHEN luminous bacteria attack a living animal, as they sometimes do, they are said to be parasitic. The unfortunate victim comes down with a luminous malady. Several instances are known among insects and crustacea. One example is the sand flea that hops about on beaches, especially near piles of dead seaweed. These animals may become infected or parasitized by the bacteria. They invade the sand flea's muscles so that its whole body becomes luminous. The sand flea gradually weakens, its movements become feeble and it finally dies, we might add, in a blaze of glory.

By far the most remarkable luminescent animals are those that permanently harbor luminous bacteria. This is an example of symbiosis, and it is found in certain fish. Such cases are not mere infections, for the fish have special luminous organs in which the bacteria live without harming their hosts. One striking instance is a fish of the Banda Islands in the Dutch East Indies. It cultivates the bacteria in gland-like cells, forming a special oval structure just under the eye. Luminous bacteria, in contrast to the small marine organisms that cause phosphorescence in the sea, glow continually. But the Banda fish has developed a method of turning its bacterial light on and off. It has a black fold of skin, like an eyelid, which it can draw over the luminous organ--hence its name: Photoblepharon (from the Greek words meaning light and eyelid)

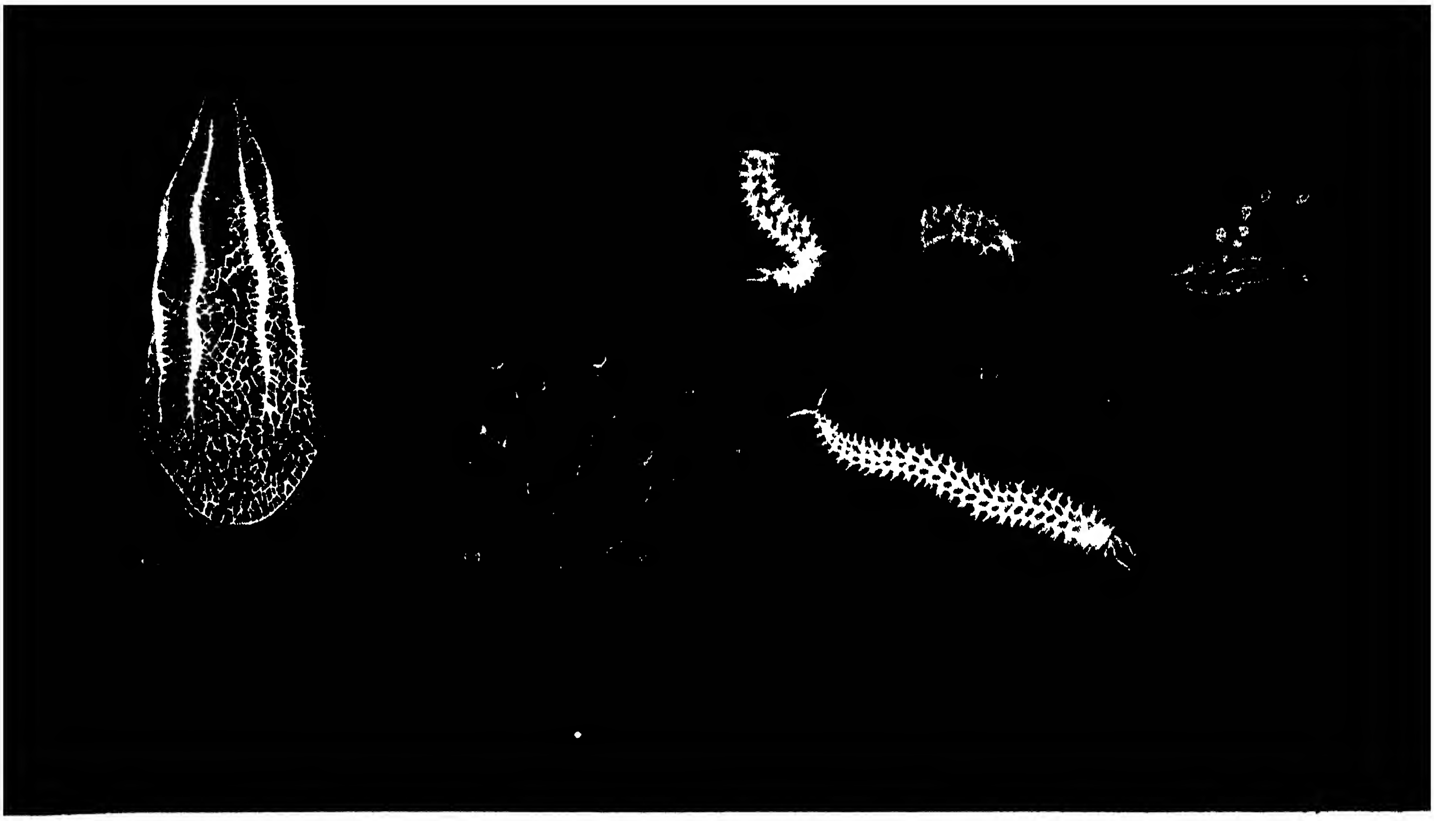
Another genus of Banda Island fish has a similar organ full of luminous bacteria, but with a different mechanism for controlling the light. In this case the organ is hinged, luminous on one side and dark on the other. The light is turned off by flipping the luminous surface against the body. The name of this fish is Anomalops (meaning peculiar eye). It is a strange sight indeed to see these Banda fish swimming through the water, flashing their large luminous organs in a series of winks.

Other luminous fish of the deep sea possess rows of photophores, or luminous spots, along the sides of the body. These look like portholes on a ship. Each species has a different arrangement of photophores and the guess has been that the sexes, living as they do in eternal darkness, recognize each other by the pattern of lights displayed.

Some animals eject a luminous fluid. For example, a deep-sea squid from the Mediterranean depths off Sicily surrounds itself with a brilliant luminous liquid when disturbed. Unlike the common squid, which ejects a black cloud of ink to conceal its position, this deep-sea cousin, living in perpetual darkness, shoots out a liquid fire. Here is one of the mysteries of evolution -one animal develops the blackest fluid known, while a close relative forms a clear, shining liquid. We can only conjecture what its purpose may be—perhaps to frighten enemies, perhaps to lure smaller animals on which it feeds, perhaps to attract the opposite sex.

A few animals have lights of two colors. The most famous is a grub-like South American beetle called the "railroad worm." It has a row of greenish-yellow lights along its sides and a red light at one end, like a train lit up at night. This lighting system is under the control of nerves which can turn on the red or yellow lights separately or together. Wher the red light alone shines, the animal looks like a glowing cigarette.

MOST luminous animals are small, but size is no barrier to chemical investigation, provided a sufficient number of specimens is available. As I have mentioned, the most valuable for chemical study is the tiny marine crustacean, Cypridina. Cypridina has a large lumi-



is almost entirely luminescent. Ctenophores, or comb jellies (13), glow with a tracery of luminescent body canals. Hydroids (14) luminesce like strange flowers. The polynoid worm (15), when it is attacked, has the faculty of leaving luminous fragments of its body behind while the less luminous head makes its escape. Bacilli of anthrax (16), like many other living things, luminesce only when they are excited by ultraviolet radiation.

nous gland that pours luciferin and luciferase into the sea water whenever the animal is disturbed. It surrounds itself with a luminous blue liquid. Cypridinae can be caught and, if dried quickly, will retain their ability to luminesce indefinitely whenever moistened. From the dried and powdered animals luciferin and luciferase can be extracted by various solvents for chemical analysis.

There is no doubt whatever that Cypridina has discovered how to make a chemiluminescent compound not known in chemical laboratories. According to present knowledge, it appears to consist only of carbon, hydrogen, oxygen and phosphorus with no nitrogen, sulphur or halogen in the molecules. The presence of phosphorus may be particularly significant. This is not, however, because the element phosphorus is luminous but because the high-energy phosphate bond has been found to play an increasingly important role in many biological processes.

The mechanism of bioluminescence is complex. The oxidation of luciferin undoubtedly takes place in a series of steps. During this process, one of the intermediate molecules retains some of the energy of oxidation. This energy-rich molecule is described as "excited." When it loses its energy, the energy appears as light.

Probably the luciferins from different animals are chemically distinct. The structural formula for Cypridina luciferin is as yet unknown, although suggestions have been made. One thing is certain: the molecular weight is relatively low. But when it comes to identifying the molecules, we have practically the whole of organic chemistry to choose from. A wide variety of organic compounds will emit light under proper conditions. Some of the better-known chemiluminescent substances are aminophthalic-hydrazid, which gives off a bright blue light; dimethyl-diacridylium nitrate, which emits light of a greenish-yellow hue, and metallic porphyrins, which produce a red light like that of the railroad worm. The spectra of these chemiluminescences are quite similar to those of animal luminescences: short bands with no lines or fine structure, with their maxima of emission in various regions of the visible, and with no ultraviolet or infrared wavelengths.

In spite of these similarities, it is quite certain that none of the organic chemiluminescent substances thus far synthesized is the same as the ones utilized in bioluminescence. We know this because none will emit light in the presence of the enzyme luciferase. This latter compound is of high molecular weight and, like other enzymes, has the chemical characteristics of a protein.

WILL it be possible to synthesize luciferin and luciferase? Chemists would undoubtedly answer an unequivocal yes, so far as luciferin is concerned; concerning luciferase, probably yes, in time. Synthesis of complex proteins is not possible now but may be accomplished in the future once their structure is known.

Will it be possible to use animal light for illumination? Calculation indicates that a room whose walls were covered with a bright culture of luminous bacteria would be light enough for reading. However, no chemiluminescence has yet been devised for general lighting. It would be overoptimistic to say that the use of living light is just around the corner. On the other hand only an unwise scientist would assert that it is impossible.

Inherent in all chemical reactions is the principle of reversibility, that is, the possibility of rebuilding a reacting substance from its products by reversing the reaction which destroys it. After a chemiluminescent substance has oxidized with production of light and formed reaction products, it could be re-formed by reversing the reaction. Thus it would be ready for a second light emission. Like the Phoenix of old, which arose from its funeral pyre in all the freshness of youth, luciferin might be regenerated for continual use as a light-giving substance.

Whether of practical utility or not, the study of animal light presents a fascinating field of investigation in pure science. Here the biologist, chemist, physicist and even the illumination engineer can meet on common ground of mutual interest.

E. Newton Harvey is Henry Fairfield Osborn Professor of Biology at Princeton University.

IN 1925 C. J. Davisson (*left*) and L. H. Germer set up their modest apparatus on a workbench in the Bell Telephone Laboratories. The apparatus, here concealed by shielding, is depicted on the cover.

DAVISSON AND GERMER

In 1927 they discovered that the electron is a wave as well as a particle, a seemingly paradoxical fact which is a part of the foundation of modern physics

by Karl K. Darrow

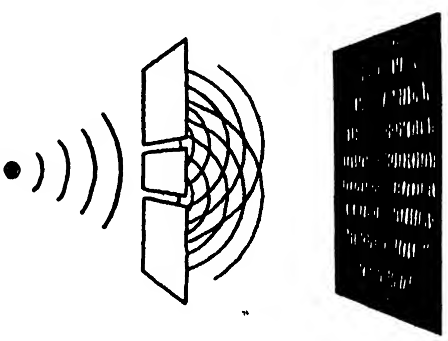
Editor's note: Modern physics is constructed of closely-fitted hypotheses and experimental observations. The historic observation of the wave nature of electrons by C. J. Davisson and L. H. Germer is a cornerstone of the theory of wave mechanics, upon which rests much of the physicist's present understanding of fundamental particles and the structure of atoms. This account of the experiment of Davisson and Germer by their colleague Karl Darrow is not only a description of how they made their discovery but also an essay in how the physicist approaches a problem of his exacting science.

FROM the latter part of the seventeenth century to the middle years of the nineteenth. physicists argued with passion a question which now appears pointless—the question whether light is of the nature of corpuscles or of the nature of waves. The argument was suspended about 1850 because of certain experiments which were supposed to prove that light definitely has the character of waves and definitely not that of corpuscles. It is now evident that the suppositious proof was not a proof, and indeed that no experiment will ever banish either view. The question on which our forefathers expended so much effort is a trick question, though the trick is one played by nature herself. It has no answer, but in hunting for the nonexistent answer we have found that the physical world is interfused with a complexity much greater and much harder to imagine than would have been the case had either of the apparently possible answers been valid by itself.

Halfway through the twentieth century, we have come to the conclusion that light is *both* of the nature of waves and of the nature of corpuscles. Various phrases have been contrived to describe this strange association of corpuscles and waves, but all of them are lame because the situation defies all ordinary language and all familiar processes of thought. The particular lame phrase that shall be used here is: *light is composed of corpuscles guided by waves.*

This article, however, is devoted to the similar law by which *electrons* are governed, and to the historic experiment by C. J. Davisson and L. H. Germer which demonstrated the law, thereby adding a new feature to atomic physics.

In considering electrons, we suffer at the start from a fault of language from which the case of light is free. The word "light" carries no connotation either of corpuscle or of wave, but the word "electron" is meant to imply a corpuscle, and it does imply a corpuscle. What we need is a word that shall specify negative electricity flowing across a vacuum or through a metal, without prejudging the ambiguous issue—for again it is an ambiguous issue --between corpuscles and waves. But we cannot use "negative electricity" safely, for negative electricity is usually taken as comprising negative ions of atomic mass in gases and conducting solutions. I have no intention of trying to increase the vocabulary of physics by introducing an invented word. Unless the reader wishes to invent a word of his own, he must use the word "electron" and do his best to regard it as a word that embraces both particles and waves in its difficult meaning.



DIFFRACTION of light waves is caused by passing them through slits. Pattern (*right*) is produced by interference of diffracted waves.

The rule that correlates the waves and corpuscles of light is very simple to express. *Corpuscles of momentum p* (momentum is the product of speed and mass) *are guided by waves of wavelength h/p.* Here h stands for one of the most famous of the great universal constants of nature, the constant of Max Planck, the pioneering German physicist who died, full of years and honors, in the autumn of 1947.

So expressed, the rule generalizes itself. If light may be so described, what is more natural than to infer that electrons of momentum p are guided by waves of wavelength h/p? Yet wisdom based on habit may be a greater obstacle to the emergence of a new idea than ignorance itself, and many a wise man overlooked this simple possibility before the proper combination of wisdom and originality brought the idea to birth in the mind of Louis de Broglie of Paris. Even de Broglie overlooked the simple consequence which is the theme of this article. Now I must make clear what I mean by saying "waves guide corpuscles."

Think of the most primitive of all "diffraction gratings"—the fence of parallel wires, evenly spaced, which Joseph von Fraunhofer first made more than a hundred years ago. Think of a narrow pencil or beam of monochromatic light—the yellow light of sodium will serve as an example—projected against this fence of wires at right angles to their plane. Owing to the even spacing of the wires, the light will be divided into several beams: one will continue in the direction of the original beam, the others will diverge at distinctive and sharply marked angles.

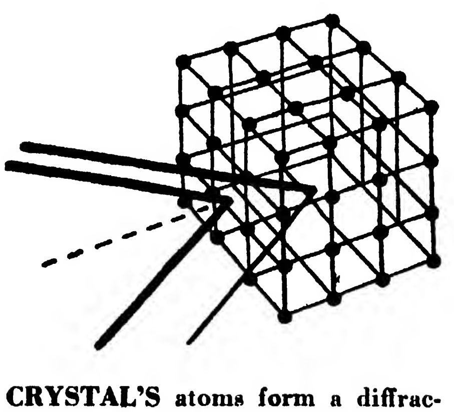
This is the phenomenon of *diffraction*, and the diverging beams are called "diffraction beams." From their angles of divergence we may compute, by a simple trigonometric formula, the wavelength or crest-to-crest distance of the light waves, for this experiment furnishes both the prime evidence that light partakes of the nature of waves and the way of determining the wavelength. If the even spaces between the wires are widened, the angles of divergence shrink. If the spaces are narrowed, the angles of divergence broaden. If the even spacing of the wires is done away with by pushing them to and fro until the intervals between consecutive wires lose all their uniformity, the diffraction beams are missing.

Here indeed is the distinctive peculiarity of waves: they notice the presence or the absence of order. They respond to an orderly array of obstacles by disposing themselves into beams in an orderly fashion. Thus, light is of the nature of waves; and yet, we know also that light consists

of energy packed into corpuscles! (Indeed, when a beam of light falls on a metal. the corpuscles pass over their energy individually to the individual electrons. each electron springing from the metal with the energy received from one sole corpuscle of light; if the energy were evenly spread over the waves, it would be so rarefied that no electron could ever gather up so much.) We try to conciliate these contradictory statements by saying that the diffraction grating forms the light waves into diffraction beams, and the waves guide the corpuscles along these beams. This is indeed a crude thing to say, and the more sophisticated a physicist is the more likely he is to decry this manner of speaking, but it will serve our purpose.

Shall we then place a grating of wires athwart a stream of electrons, and look for diffraction beams on its far side? No, this will not work. because of a difficulty of scale. The wavelength of electrons at any feasible speed is too small. Their momentum (speed times mass) is very high as compared with the momentum of visible light. The "rule of correlation" between waves and corpuscles—wavelength of waves is h divided by momentum of corpuscles—teaches us that for electrons of any convenient speed and a wire grating of any feasible spacing, the diffraction beams (if any) will be pinched into such small angles with reference to the main forward-faring beam that we shall be unable to distinguish them. Conceivably we might use electrons so very slow-moving that the wavelength would be large enough to yield a broadly diverging pattern of diffraction beams; but in so slow-moving a stream the repulsions between the electrons would spread out the beam until it became so vague that again the phenomenon we seek would be blotted out. We must take electrons of a convenient speed—the speed conferred on them by a potential difference of 100 volts is a convenient one—and seek for a grating of obstacles regularly spaced, with a spacing of the proper scale.

Now, a *crystal* is just such a grating because of the orderly arrangement of its atoms and the narrowness of the spacings between them. Accordingly, it was a crystal which in the hands of Davisson and Germer formed a stream of electrons into distinct and unmistakable diffraction beams, and thus proved that electrons are under the guidance of waves.



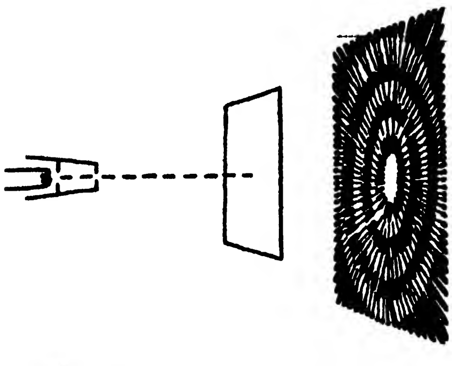
CRYSTAL'S atoms form a diffraction grating when electrons (*left*) are directed against them. Deeper atom layers also diffract electrons.

BUT let me interrupt the argument to introduce the major figures of this story and the scene of their researches. Davisson. a native of Illinois, a doctor of philosophy of Princeton University (where he worked on the emission of positive ions by incandescent metals) and a professor of physics in the Carnegie Institute of Technology, came to the Bell Telephone Laboratories in 1917 to participate in the research work of World War I. There he remained until he retired in 1946. He was in his early forties at the epoch when this story commences. Germer, a native of Chicago, just turning 30 at the time of these experiments. made his debut as a physicist at the Bell Telephone Laboratories. His measurement of the energies of electrons emitted from hot filaments. made at these Laboratories. had served as his doctoral thesis at Columbia University. Later he continued for years to develop the applications of electron diffraction. These. however. were not foreseen before the discovery. which confuted for all time (not that it still needed confutation) the erroneous idea that "pure" science cannot flourish except in academic institutions.

From this point on I might leave the reader under the impression. implied though not demanded by what has gone before, that Davisson and Germer set out to test a prediction made by Louis de Broglie. But science does not always advance in such a logical fashion. and in this case particularly it did not. De Broglie. as I have already said. apparently did not foresee that electrons might be diffracted by crystals. Though he did associate waves with electrons according to the rule of correlation which I gave above (and which often bears his name), he did it in order to make a theory of the hydrogen atom. As for Davisson. he was exploring the reflection of electrons by surfaces of metals, with no particular aim beyond the furtherance of knowledge.

Metals normally are aggregations of tiny crystals turned in every way. In this normal condition. they do not form a single diffraction grating. Therefore Davisson did not observe diffraction beams. But he did observe surprising preferences of the reflected electrons for certain directions over certain other directions of rebound. (The technical way of expressing this is that the distribution-in-angle of the reflected or "scattered" electrons showed a strange and striking dependence on angle.) This body of facts Davisson interpreted in terms of the structure of the metal atoms. He had not yet invoked either the significance of the crystalline arrangement of the atoms or the idea of waves.

At that critical juncture. an accident later recognized as happy brought about the transformation of a large part of the metallic reflector into a single crystal. Here I quote from Germer. who has graciously supplied his recollections for this article:



PATTERN of diffraction similar to that produced by light is created when electrons are beamed through a thin foil made up of metal crystals.

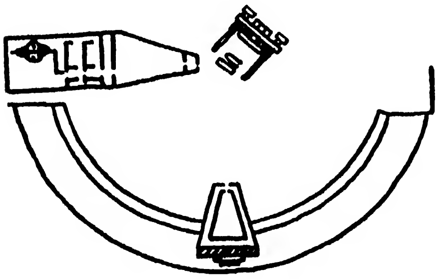
"In the spring of 1925 occurred an accident which led to the discovery that the crystalline arrangement of atoms did, after all, take part in determining directions of electron rebound. The accident happened while air was being exhausted from a glass bulb. somewhat like a glorified and very special radio tube, which contained a metal reflector upon which these experiments were to be continued. It consisted of a break in the apparatus which allowed air to rush in, and fortunately it happened at a time when the reflector was red-hot. The result was oxidation of the reflector. Here again good fortune intervened. The oxidized and blackened reflector might very well have been thrown away and a shiny new one substituted for it. The course of the experiment was otherwise. It was decided to clean the oxide from the surface by heating it for a long time in hydrogen. This was done, and at the end of this long annealing process the reflector consisted no longer of a great many tiny crystals, as metals usually do, but of a very few large ones. This change in number and size of crystals was not noticed at first. but when experimentation was begun again the phenomena were startingly changed. The distribution-in-angle of the electrons rebounding from the re-crystallized reflector was quite altered and much more complicated."

This observation proved that the structure of the metal atoms was not the only source of the singular scattering phenomena. Davisson conjectured that there might be "transparent directions" in the crystal, along which the electrons could travel without suffering reflection or disturbance. The key had not been found as yet, but the idea of diffraction

emerged in the course of the months, and in the following year Davisson calculated where the diffraction beams should lie and set about to find them. On January 6, 1927, Davisson and Germer found a strong and sharp diffraction beam due to the arrangement of atoms in rows in the crystal surface, and it was at the proper inclination —that is to say, it was just the beam which should have been formed by waves of the wavelength given by the rule of correlation.

It will help now to look at the illustration in this column. At the upper left an "electron gun" shoots electrons in a steady stream toward the metal crystal to the right. The electrons come from an incandescent filament, and there are various voltages applied between the various slits and the casing of the gun. This design requires careful planning, but its details are immaterial to our present purpose.

The neatly defined beam of electrons, of a uniform and controllable speed, impinges on the crystal. The reflected or "scattered" electrons fly off in all directions from the surface of the crystal, and most of them depart from the plane of the drawing; but this also is immaterial, for it is possible so to orient the crystal that diffraction beams will appear in this plane of the drawing. In the same plane

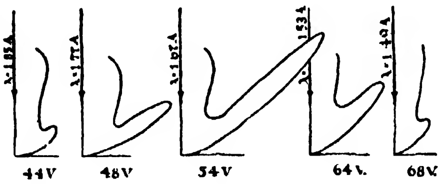


APPARATUS of experimenters fired electrons from gun (*left*) at crystal. Diffracted electrons were gathered in a movable collector at bottom.

swings an "electron collector" that is moved from point to point along the arc which also appears in the drawing, sojourning at each stopping point long enough to collect an appreciable number of electrons. All of this apparatus was enclosed, while the experiments were going on, in an evacuated tube of glass. The presence of air would have ruined the observations, for the air molecules would have dispersed the electrons and blotted out the beams.

Next we should consider a diagram of the diffraction beam. The curve in the center indicates a beam which is strong and sharp. The curves to the left and right indicate beams which are less marked. The difference springs from the fact that the middle curve depicts electrons of the speed corresponding to a voltage of 54; those on the left represent lesser speeds and those on the right, greater. Smaller speeds correspond to greater wavelengths, and vice versa; the wavelengths in Angstrom units (one Angstrom = 1/100,000,000 cm) are written along the vertical axes. The inclination of the beam varies with the wavelength, but this is scarcely obvious in the pictures. Much more obvious are the differences in the strength of the beam.

But why should the diffraction beam be



CURVES plotting the voltage and wavelength of electrons diffracted in apparatus lent further support to the Davisson-Germer experiment.

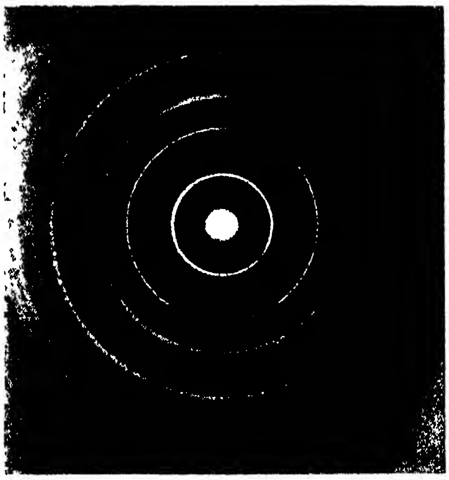
favored by a certain particular electron speed, and impaired at other speeds? Nothing I have thus far said suggests anything of the sort, and indeed nothing of the sort would occur if this were diffraction by wires in a plane or by an optical diffraction grating. This complication arises from the fact that the atoms of the crystal form a *three-dimensional* grating. The atoms of the surface layer are indeed arranged in evenly spaced rows of evenly spaced atoms. If they alone were operative, a change in the electron speed would swing the diffraction beam to another angle without blunting or reducing it. But beneath the surface layer there is another layer of evenly spaced atoms and beneath these there are others and others. These collaborate in the diffraction, conspiring to magnify the beam for a certain optimal speed, which happens to correspond to 54 volts, conspiring to attenuate it more and more as the speed departs from this optimal value. This is not a very easy thing to grasp: what is simple in two dimensions is often complicated when a third dimension enters into the picture. Suffice it here to say that the favoritism shown the diffraction beam by this peculiar value of electron speed adds support to the theory.

Much has been done in this field in the years since these first experiments proved that electrons share with corpuscles of light the universal deference of particles to waves. "Universal" is not too strong a word: other experiments like those of Davisson and Germer have shown that atoms, nuclei and neutrons all submit to the guidance of waves, and always the wavelength of the guiding waves is h divided by the momentum of the guided particles. To identify these with electromagnetic waves, to identify them with acoustical waves, to invent an ether to sustain them—all such enterprises are worse than fruitless. Even the metaphor of "guidance" speedily loses its fitness when one attempts to penetrate further into the intricate association of particles and waves. We shall enter into it no further; but two things remain to be said to round out this article.

FIRST, to give credit where credit is due: the young German physicist Walter Elsasser was the first to publish, in a brief letter to a German journal, the idea that electrons may be diffracted by crystals. He adduced as evidence the singular phenomena which Davisson observed in 1925 and earlier, when the electrons were being scattered by polycrystalline masses of metal. It does not appear that these phenomena prove the idea, nor that Elsasser's letter affected the subsequent course of the experiments of Davisson and Germer, but it should not be forgotten that Elsasser bridged the gap which the theoretical physicists of the time had left open.

Second, I must not leave uncorrected the implication that a mass of small crystals is unable to testify to the diffraction of electrons. When a beam of electrons passes through a very thin sheet of metal composed of many tiny crystals, and a photographic plate parallel to the sheet awaits the electrons at a suitable distance beyond, the plate—after exposure and development—reveals a glorious spectacle of concentric rings. These are due to diffraction beams, and so they add their testimony to the doctrine that electrons are guided by waves. These rings were first produced by G. P. Thomson (now Sir George Thomson) of England, who shared the Nobel Prize with Davisson for the coincidental making of one of the most notable discoveries of modern times.

Karl K. Darrow is a physicist at Bell Telephone Laboratories and secretary of the American Physical Society.



PHOTOGRAPH of electron diffraction pattern, made by method shown at top of opposite page, is added proof of the electron's wave nature.

Smelting Under Pressure

The U.S., world's largest producer of iron and steel, must have more of both. One way to ease the shortage is to increase the pressure of blast in blast furnaces

by Leonard Engel

THE blast furnace, certainly one of the half-dozen fundamental machines of our industrial civilization, was invented by an unknown Central European iron-maker some time before 1340. It has remained essentially unchanged for more than 600 years. The modern blast furnace, for all its awesome size and accessories, differs little in principle from the original. Within the past year, however, a major innovation in blast furnace practice has made its appearance and passed its tests. It consists merely of raising the pressure of the seething atmosphere within the furnace. The comparative simplicity of this idea is a poor measure of its technological and economic importance.

At Cleveland and Youngstown, the Republic Steel Corporation has modified two of its blast furnaces so they may operate under pressure. By this single alteration, Republic has substantially raised the output of iron from each furnace and has cut coke consumption by 250 pounds per ton of iron. And, significantly, it has done so while using inferior ores.

The performance of Republic's two furnaces comes with dramatic timeliness. The U.S. and the world are critically short of iron and steel. American furnaces and mills, which already produce more than half the world's iron and steel, are working nearly at full capacity. To keep our economy functioning smoothly, an increase in their productive capacity is urgently needed.

If this is true, it might be asked why we do not expand our iron-and-steel-producing plant. The answer is that plant expansion is slow and expensive. And to complicate the problem, our supply of top-grade iron ore and coke is dwindling. This means that more finished products must be made from poorer raw materials, with the least possible construction of new plants. That is precisely what the new pressure method promises to accomplish. It is estimated that if pressure equipment were installed in all of the 234 blast furnaces in the U.S., without any new plants and in spite of the declining quality of ore and coke, American pig iron production would be increased from the present 58.5 million net tons to at least 75 million tons a year.

To understand how the pressure process works we must briefly consider the art of iron-making. Until the invention of the blast furnace, iron was available only as wrought iron. This form, in which many impurities of the ore remain in the metal, can be wrought (hammered) into some useful shapes, but cannot be cast or made into steel. Wrought iron was produced in small furnaces that did not melt the ore. Iron for steel requires a more elaborate process because of a peculiarity of the oxide ores of iron: iron oxides are reduced, *i.e.*, the oxygen is separated from the iron, at a temperature of about 1,100 degrees F. This is approximately 900 degrees below the melting point of cast iron. To run off the major impurities in the ore as slag and produce metal suitable for steel-making, the iron must be melted. But the melting must not take place in close proximity to the reduction process because reduction does not proceed efficiently at the temperature of molten iron. The problem is solved in the blast furnace by making the furnace very tall and carrying on reduction and melting in different parts of the furnace.

The blast furnace makes iron from ore, coke, flux (usually limestone or dolomite) and air. Air, which is the "blast" of the blast furnace, is reacted with coke at the bottom of the furnace to produce carbon monoxide and heat. The carbon monoxide reacts with ore in the upper part of the furnace to produce iron. The iron then falls through the burning coke, where it melts, permitting the impurities to separate and combine with the flux to form slag. The molten iron collects at the bottom of the furnace and the slag collects in another molten layer above the iron.

The product of the blast furnace, pig iron, actually contains a higher total of impurities than wrought iron. The major impurity, however, is four to five per cent of carbon. Fortunately this gives iron desirable casting qualities (a sharply defined melting point and the property of expanding on solidification so that molds are completely filled). Carbon is easily burned out, in any case, by steel-making Bessemer converters and open-hearth furnaces.

Like so many other phrases in the furnaceman's language, the term "pig iron" recalls the age before steel, when blast furnace iron was cast into 80-pound units in molds on the floor of a shed next to the furnace. In the furnaceman's imagination, the trench from the furnace taphole, together with the group of molds, resembled a sow and a litter of suckling pigs. Today, of course, the pig molds are gone from the shed. Molten pig now goes directly to the furnaces which make iron into steel or to the casting machines. But tapping the furnace is still "making a cast," the shed remains the "cast house" and the foreman of the tapping crew is the "keeper of the cast house."

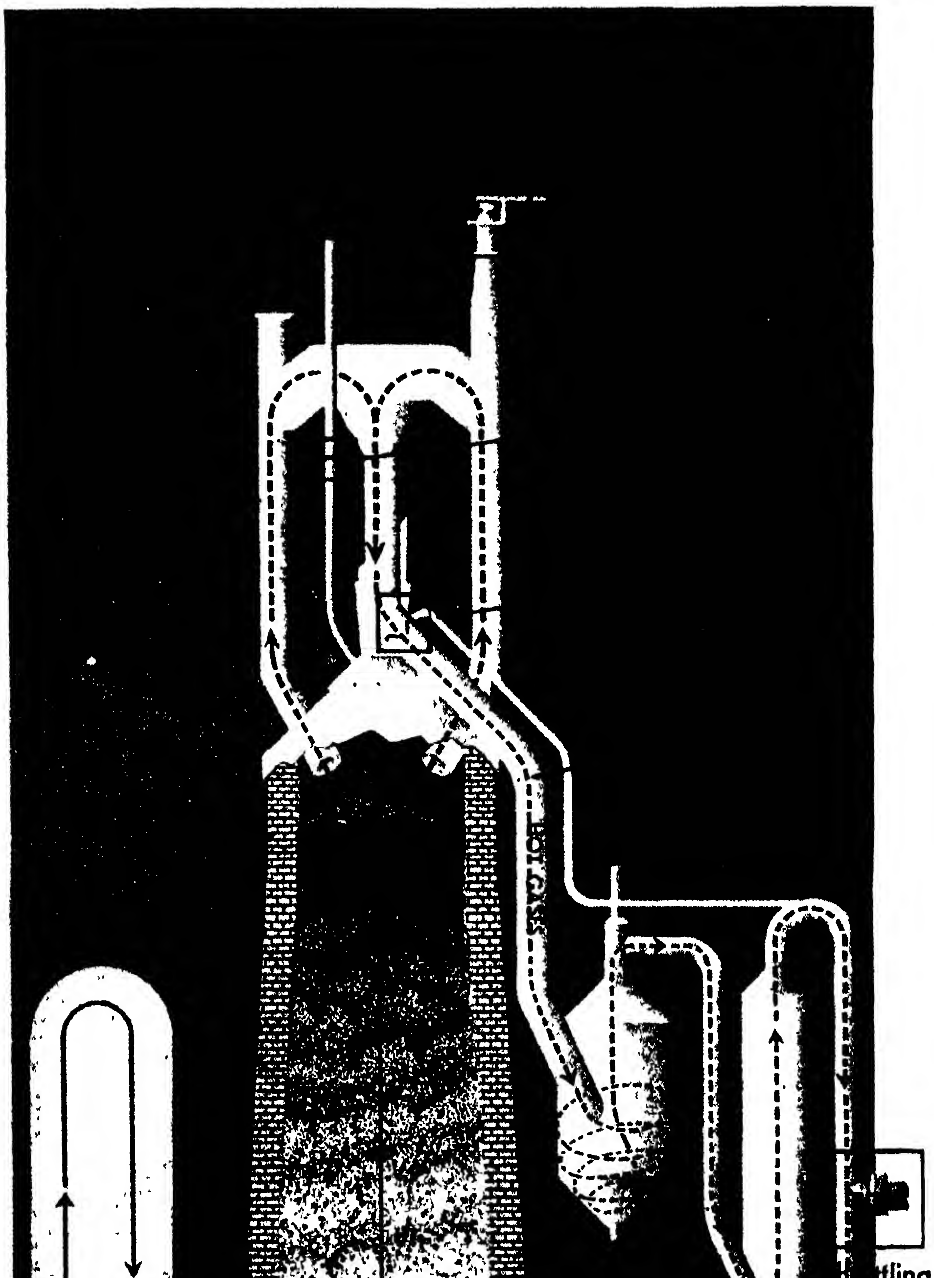
In early blast furnaces the fuel was not coke but charcoal. Coke was introduced in 1519 by iron-makers in England, where wood has been scarce since the Middle Ages. Three centuries later, in 1828, British iron-makers made another innovation, heating the blast before it went into the furnace. But from that time until the present development of pressure operation, there were no important changes in the blast furnace itself. Advances were confined to auxiliary features, such as the burning of furnace gases to produce power as a by-product, developed in several countries around 1880. This does not mean that there has been no increase during the past century in the output of furnaces; a modern blast furnace producing 1,250 tons of pig a day has more than 60 times the capacity of those which operated a century ago. But the increase has come about almost entirely through mechanizing the handling of raw materials and enlarging the blowers and furnaces to Bunyanesque size. A modern blast furnace is 30 feet in diameter and towers 110 feet above its dust-laden surroundings.

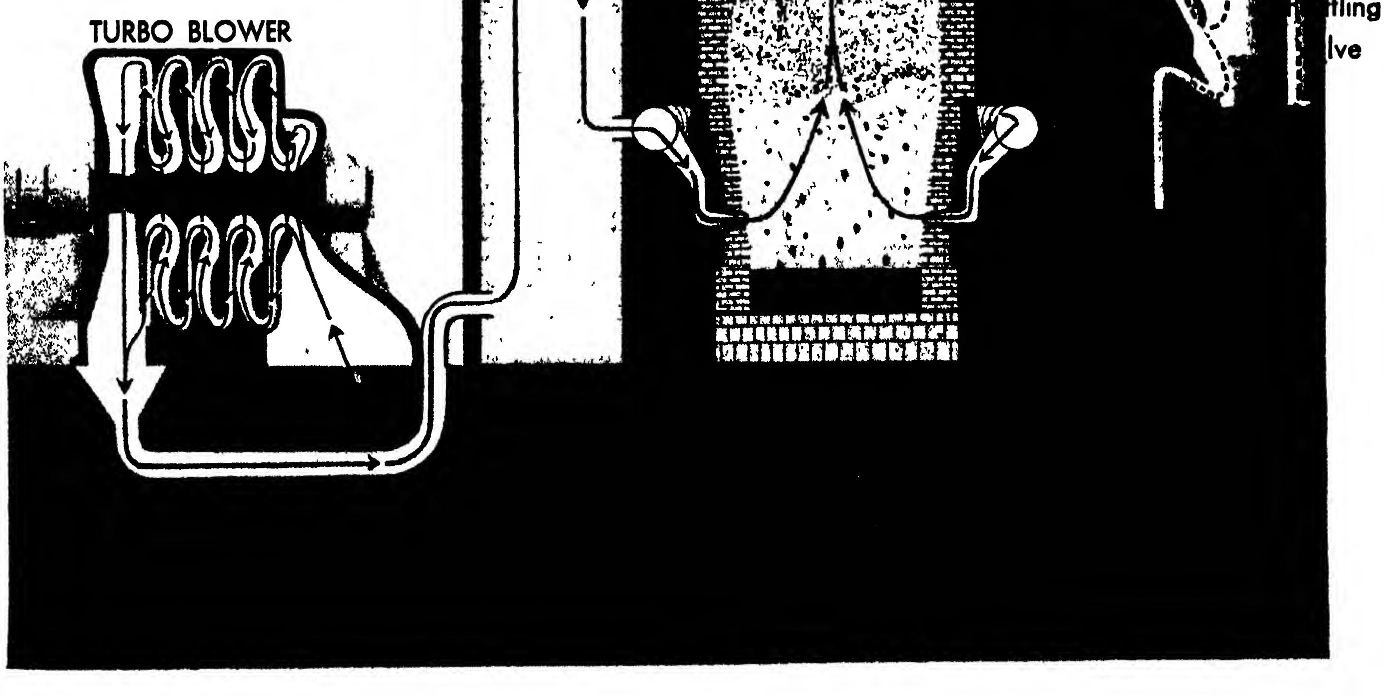
THE blast furnace has been slow to change partly because of the weight of tradition and partly because it is a peculiarly difficult object for research. Since it must be large enough to have two dis-

tinct temperature zones, the blast furnace cannot be reproduced on a laboratory scale. After six centuries, therefore, exact knowledge of events in the furnace interior is still limited—a fact which is reflected in the furnaceman's habit of referring to the furnace as "she." Iron-making, like love-making, remains largely an empirical art.

Until fairly recently the principal obstacle to raising the output of the blast furnace was the inadequacy of the blowers which supplied the volume of air needed to feed its iron-making reaction. It was impossible to pump in enough air to react as much ore, coke and flux as could be charged into the furnace. Within the past three decades, however, blower design has come so far that blowers with practically any desired capacity can now be built. But air supply is still the chief bottleneck in boosting furnace productivity, for there is a limit to the rate at which air can be blown into a furnace. If the "wind" is increased even slightly beyond a certain point—determined by the size of the furnace and the fineness of the ore—a large percentage of the ore, sometimes as much as a sixth, is blown completely out of the furnace as "flue dust."

In American furnaces this is a serious problem. Most American ores, particularly those from the fabulous Mesabi Range, are rather fine weathered earths.





RESPIRATORY SYSTEM of a blast furnace is traced by red arrow beginning at the lower left of this diagram. Unchecked, the air tends to blow fine material out of the furnace. But when the furnace is throttled with the comparatively minor modifications indicated by four small squares, pressure and furnace capacity can be increased while keeping the "charge" from blowing away.

As a result, the largest American furnaces are limited, under the best conditions, to a wind of 75,000 cubic feet per minute delivered at the tuyères (pronounced tweers), the nozzles through which air enters the furnace. This limits their iron output to 1,250 tons a day. Under average conditions, since an ever-larger percentage of the available ore is fine stuff, the limits are 65,000 cubic feet per minute of wind and 1,150 tons daily of iron. A partial solution of the problem, currently being adopted by some iron-makers, is the preliminary sintering of fine ores, *i.e.*, roasting them with coke to form clinkers. Pressure operation seems a more effective approach.

The basic feature of the pressure technique, which is known as "high top pressure blowing," is a valve or some other form of throttle to block the flow of air out of the furnace and build up pressure inside. Pressure does two things to a furnace. First, because the usual draft is blocked, it sharply reduces wind velocity through the furnace. Second, it distributes the gas more uniformly through the dense "stock" of iron-making materials which fill the furnace. When the gas velocity is reduced, more wind can be blown, more ore smelted, finer ores used and more iron can be made without generating excessive flue dust. Furthermore, with reduced gas velocity and improved gas distribution, the carbon monoxide in the furnace gas remains in longer and more uniform contact with the ore. Thus the carbon monoxide is utilized more efficiently and coke consumption is lowered.

IN its first two pressurized furnaces, Republic Steel has used comparatively low pressure—about 10 pounds per square inch above that in the conventional furnace. At this pressure 10 to 20 per cent more wind can be blown. The result is a rise of up to 15 per cent in the amount of iron produced from rather lean ore containing 48 to 50 per cent iron, with a 10 to 15 per cent saving of coke and a 30 to 70 per cent reduction of the flue-dust loss. Higher pressures will further enlarge these gains. Moreover, the pressure furnace can be manipulated to maximize any particular increase in production or economy that the current conditions demand.

In two of the five additional furnaces which it is pressurizing this year, Republic plans to raise the pressure to 20 pounds per square inch above normal. In one of these, a unit at Warren, Ohio, will be installed one of the largest blowers ever built, an Ingersoll-Rand unit capable of delivering over 105,000 cubic feet per minute through the tuyères under relatively high pressure. This combination of wind and pressure—according to figures prepared by engineers of Arthur D. Little, Inc., designers of the installation—will result in an increase in iron output of 40 per cent, from the use of an ore containing 50 per cent iron and good-sized particles. Or, if it is necessary to use leaner ores, the same wind and pressure formula will make it possible to maintain substantially normal production from ores as lean as 40 per cent iron, which now require preliminary concentration if they are to be used effectively in blast furnaces. In either case, the saving of coke would be some 200 pounds a ton and flue-dust losses would be cut in half. To illustrate the flexibility of pressurization just a little further, if 20-pound pressure were combined with the normal wind volume of 75,000 cubic feet per minute, iron production would go up less and might even decrease somewhat (depending on the ore). The saving of coke, however, would exceed 300 pounds a ton. If the wind volume were cut further back, say to 60,000 cubic feet a minute, flue-dust losses would all but disappear and very large percentages of fine ores could be used without sintering and without any sacrifice of iron.

During the past two years furnacemen have also been experimenting with a second new method of boosting furnace output—enrichment of the blast with oxygen. Increasing the air's natural concentration of oxygen from 20 to 25 per cent raises iron production one-sixth. But oxygen enrichment does not permit any saving of coke. Since saving coke is currently almost as important as making more iron (coking coal quality is declining more rapidly than ore quality), pressure will probably be preferred to oxygen enrichment for most furnaces. Besides, the pressure installation is cheaper.

Most furnaces can be converted to pressure operation in less than a week for about $125,000—one per cent of the present $10 million cost of a new furnace. The changes required are essentially devices for throttling exhaust gases and for sealing the pressurized furnace. Since it has long been the practice to install extra blowing capacity in case a dying fire must be stimulated, the majority of furnaces already have adequate blowers. But even if new blowers must be installed, the total cost will go only a little beyond $1 million.

A number of imaginative furnacemen looking into the future see a combination of pressure and oxygen-enriched blast which would double furnace output. The use of pressure and oxygen together will bring another major innovation in furnace operation: a new system for handling raw material. A furnace smelting 2,000 tons of iron daily would require 6,400 tons of ore, coke and flux a day, or 3.2 tons of raw material for every ton of iron produced. This means that seven full railroad cars of these various ingredients would have to be fed into the furnace every hour. Such a spate of material is far beyond the capacity of the "skip hoist," the standard double-track cable railway which for a century has moved ore, coke and flux up the side of the furnace from storage bins to the charging hopper. In place of the skip hoist, a system of overhead bins fed by radial conveyor belts from separated unloading points has been proposed. This would meet the raw material requirements of any foreseeable combination of wonderful new iron-making techniques.

The inventor of blast furnace pressurization is Julian M. Avery, a New York chemical engineer. A dozen years ago Avery, now vice-president of the Hodges Research and Development Corporation, made one of the rare studies of blast furnace metabolism. Becoming convinced that pressure would raise furnace efficiency, he worked out and patented the details of pressure operation.

Avery put forward his conclusions in a paper at the 1938 meeting of the American Institute of Mining and Metallurgical Engineers. Most steelmen dissented sharply, and pressure did not receive a trial until 1944. Then the War Production Board, goaded by the shortage of pig iron and scrap, negotiated a license agreement with Arthur D. Little, Inc. (to whom Avery had assigned his patents) and awarded Republic a contract for a test installation. This was made on furnace No. 5 at Republic's Cleveland plant.

Because of mechanical difficulties, the wartime test was generally disappointing. But the results were good enough during the few weeks the pressurized furnace actually operated to decide Republic and Little on a further trial. After the war, Republic's furnace No. 5 at Cleveland and No. 3 at Youngstown were converted to pressure. They have been operating that way ever since.

The mechanical difficulty responsible for the drab outcome of the first trial was the failure of devices which sealed the furnace at the point where its charge was loaded. A successful system was worked out, however, by the pioneer Republic-Little engineering group, which was headed by B. S. Old of Little and the late J. H. Slater of Republic. Pressure has given no unusual trouble since. Although the smelting reactions proceed at an accelerated rate, pressure has no effect on furnace temperatures. Consequently it does not affect the chief item in furnace maintenance, the life of the lining. Both Cleveland No. 5 and Youngstown No. 3 are well on the way toward completing two million tons—the usual output between overhauls—with the same linings.

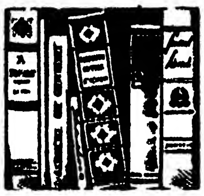
In the Cleveland furnace the exhaust gases are throttled and pressure built up by a set of valves. At Youngstown No. 3, some of the gases are throttled by being led through an experimental turbine, an arrangement which merits notice because it enables this pressurized furnace to produce not only more iron, but more power. In conventional furnaces recovery of the exhaust gases—which are rich in carbon monoxide and may be burned—yields enough fuel to preheat the blast, to drive the blowers, and, in the case of a large furnace, to generate some 8,000 kilowatts more for other purposes about a plant. Although the extra pressure of the Youngstown furnace is only 10 pounds per square inch, it has been calculated that a throttling turbine might recover 2,000 additional kilowatts—a clear profit in power since the turbine takes nothing from the fuel value of the gas. A large turbine-equipped furnace under pressure of 20 pounds per square inch would recover more than 6,000 kilowatts, according to these estimates.

POWER, of course, is a secondary consideration in blast furnace operation. Nonetheless the extra wattage yielded by the throttling turbine is important because it means greater economy in the making of iron and steel. In coming years, the United States will have an increasing need for these various advantages of pressure smelting. By making possible the production of more iron from poorer raw material, it may resolve the dilemma inherent in the shortage of iron and steel.

To an extent not generally appreciated, U.S. industrial strength is based on an accident of nature: the unique geographical combination of Minnesota and Michigan ore, Appalachian coking coal and the Great Lakes highway. On this triple gift of nature rests our towering steel industry. To it we owe three generations of the cheapest and most abundant iron and steel in the world—and, in the final analysis, our standard of living. But one part of the dowry is giving out. The high-grade, open-pit ore of Minnesota's Mesabi Range is largely used up; some observers say 10 years will see virtually all of it gone. To prevent the loss of Mesabi ore from reducing our standard of living, we are compelled to turn to new and more efficient ways of making iron and steel. Among those that have appeared thus far, pressure operation of the blast furnace is most promising.

Leonard Engel is a free-lance writer.

FURNACE IS TAPPED when molten iron has trickled from the charge of ore, coke and flux. Here the iron is run into ladles at the Ford Motor Company's River Rouge plant, which operates its furnaces at conventional pressure. Base of the furnace and air-carrying tuyères are at upper right.



BOOKS

Geoffrey Gorer's "The American People": An anthropologist's critical view

by Ralph Linton

ONE phase of the American "need to be loved" which Geoffrey Gorer stresses so much in his book "The American People" (W. W. Norton & Co.), although it is a phase which he fails to mention, is our almost adolescent eagerness to know what other people think of us. Books about America and Americans written by foreigners always find a larger and more interested audience in this country than in their authors' homelands. I feel sure this book will be no exception, for it is clever and exceedingly well-written. The author's literary skill, spiced with a considerable admixture of sly malice, is sure to keep the reader interested from start to finish.

The book describes those aspects of modern American life and character which appear most striking to an Englishman, and attempts to account for these on the basis of modern psychoanalytic theory. Since the author has invoked the name of science to give his work greater authority, it seems justifiable to consider the techniques he has employed. These techniques certainly do not meet any of the requirements of science as they are ordinarily understood. Although the author speaks with great assurance about American behavior and attitudes, he gives no indication of the way in which the crude data were obtained. He pays frequent compliments to the Margaret Mead-Ruth Benedict school of anthropologists, but anyone familiar with their techniques knows that they vary from precise, careful and well-documented studies of child care and adult behavior to a free exercise of feminine intuition unhampered by either facts or frequencies. Gorer also fails to give any indication of the length of the series of observations on which his conclusions are based, or of the groups in this country from which his subjects were drawn. Instead he lists the parts of the United States in which he has traveled. No statistical methods were employed at any stage in the study.

In the absence of any precise information as to how the author got his data or arrived at his conclusions, one must deduce these from the evidence provided by the book itself. It appears that Gorer's American contacts have been almost exclusively with the members of two groups: middle-aged clubwomen, who are always eager to extend dinner invitations to presentable and amusing young Britishers, and the semi-Bohemian intelligentsia of New York and vicinity.

To his limited range of observations he has applied purely subjective methods of analysis. While the reviewer recognizes that in certain cases such methods are not only justified but may even be the only ones applicable, it would seem highly desirable to check the results by more objective techniques wherever possible. It would also seem desirable to supplement immediate observations by background information. Even slight attention to the known past of American culture, which is also generally accepted as a proper field for anthropological study, would have raised considerable doubts as to the validity of some of the author's conclusions.

Gorer employs an approach which is psychoanalytical without slavish adherence to the theoretical tenets of any one school. Modern American attitudes and institutions he explains as results of the individual's projective system. Infantile or childhood experience shapes all adult behavior. The future American citizen, says Gorer, raised on a formula and tormented by hunger because books say he should get only so much food at such and such hours, as an adult takes an almost psychopathic interest in feminine bosoms, manifests an abnormal craving for milk, and fears that aid to Europe will result in starvation for America. Oversolicitous mothers and schoolmarms urge him to the limits of his powers, impressing him with the importance of being popular and successful and filling him with an overwhelming fear of being a "sissy." At the same time, Gorer states, they provide him with a feminine type of conscience or super-ego quite at variance with the demands of business. The result is the American pattern of exaggerated competition in all spheres and puzzling differences between idealistic statements and anything but idealistic behavior.

While the author's description of this adult behavior is accurate enough--at least for the American groups he knows—it would be interesting to know the sources of his information on the overwhelming influence of mothers and schoolmarms. Outside the narrow confines of suburbia, most American families include fathers who are far from negligible quantities either as ultimate sources of reward and punishment or as models to be imitated by the growing boy.

THE author dwells at considerable length on the American child's rejection of paternal authority. (If this is true in the American hinterland, the son had better not let his father find it out.) Gorer assumes this rejection to be a revolt against the Old World ways of the immigrant parent. The son wishes above everything to become a full-fledged American, indistinguishable from other Americans, and despises his father for his foreignness. It is easy to see how such an idea could originate from discussions with urban intellectuals, many of whom do have such a background. However, there is a fine old tradition of American resistance to parental authority which can be traced as far back as Benjamin Franklin, Davy Crockett and Huckleberry Finn. Whatever it was that set these sons against their male parents, it certainly was not the latter's accents or fondness for un-American cooking. May not the truth of the matter be that in a rapidly changing society, such as our own has been throughout its history, few fathers could offer their sons rewards for submission which would equal those they could get by striking out for themselves?

According to the author, this rejection of authority carries over into all phases of our national life. Americans fear any sort of strong government because they subconsciously identify it with paternal authority. They are less disturbed by the scandals of a Harding administration, Gorer thinks, than by the implications of power in a fourth term for Roosevelt. With this attitude there goes a deep suspicion of anyone who enters politics for avowedly altruistic motives. The grafter can be understood and occupies the quasi-respectable position of the bootlegger under prohibition, but the man who serves honestly and at financial loss to himself must be trying to establish some sort of control over others and enjoying such control.

Gorer's typical American childhood situation, in which the love of the mother can be won only by success in competition with other children, also has its repercussions in adult behavior. In adolescent years this is reflected in the institution of "dating."

Dating, according to the author, is a typically and almost exclusively American custom. Of course, he admits, young people of opposite sex seek each other out in all countries, and "love laughs at locksmiths." However, in most societies these contacts are either a courting preliminary, the object being matrimony, or direct sexual expression. Many primitive cultures allow for a period of sexual license and experimentation among their adolescents. Gorer finds that the unique feature of American dating is that it is neither a sexual overture nor a courting technique but rather an elaborate game played largely for prestige purposes. This may be carried to fantastic lengths. In one midwestern coeducational institution,

for example, the campus belles rarely spent an entire evening with one date. They portioned out their evenings, an hour to each boy. Such dates can scarcely have been amusing for either party. But for the girl it was a collection of scalps, for the boy a sign that he could get a date with the most popular girl on the campus. This description of Gorer's is certainly accurate for college communities and the upper class in general, but it would be interesting to know how far it is a general American pattern. Alfred C. Kinsey's recent work suggests that the adolescent behavior of a large sector of American society has more in common with that of the Trobriand Islanders than with that of The Four Hundred.

In spite of our American competitiveness, Gorer believes, the desire to be loved is the mainspring of our national character. As a nation we yearn to have people love us and admire us. We are upset if shopkeepers, garage attendants and waitresses are not cordial and friendly. Whites even expect these responses from Negroes, who have little reason for friendliness toward members of the dominant group. The need to be loved even influences our foreign relations. We expect other nations to recognize our benevolence, our rightness and our friendliness and to meet us with love and gratitude. When they fail to do this, we feel that they have taken advantage of us. Although one must agree with the essential truth of these statements, one wonders whether it is necessary to invoke an infantile trauma to account for such attitudes. Annoyance with beggars who jeer at their benefactors after asking alms is not limited to citizens of the U.S.

The author does not underrate the generosity of Americans as a group. Whether his interpretation of the reasons for this generosity is correct or not is another matter. He says that we value money as a symbol of success, not as a value in itself. Once the money has been made, it will be rapidly disposed of either in charity or by transforming it into other prestige symbols. "A man is known by his wife's fur coat," while the wife prides herself on having a home decorated according to the latest suggestions of home-making magazines. "It is rare in American homes," says Gorer, "to come across that crowded absence of taste which distinguishes so many European interiors, and it is almost equally rare to come across a house with decorations distinctive enough to be remembered."

Gorer sees the Americans as a highly pragmatic people with what he calls an "atomistic" view of the world, referring not to atom bombs but to a curious ability for dealing with things and situations as so many unrelated items. This is responsible for the constant inconsistencies in our political and economic behavior and keeps us, for the most part, from realizing that there are inconsistencies. He finds this reflected even in our dual symbolism for our country. At one moment we represent America as the benevolent Goddess of Liberty and at the next as Uncle Sam, the shrewd Yankee horse-trader.

The American male, Gorer says, leaves the world of relations to women. He feels apologetic about any aesthetic interests he may have, but in the world of things he is supreme. No other people have so completely dominated their materials nor carried technology to such heights. But although we pride ourselves on our inventiveness, we have few basic inventions to our credit. We have taken the inventions of other nations, improved upon them and adapted them to mass production. Our slogan has been to get the most things to the most people. Gorer quotes as typical of American values an alleged remark of President Roosevelt: "If I wanted to point out to the Russians the superiority of the American way of life, I should try to get just one book into their hands, the Sears, Roebuck catalogue."

Curiously, Gorer does not seem to have discovered any feature of American child-rearing to account for this attachment to things and for skill in manipulating them. Neither does he seem to be conscious of the basic contradiction between that most American invention, the assembly-line, and the American resentment of authority. If the latter is as universal a characteristic as he assumes, it is difficult to see how the assembly-line technique of mass production could have been developed.

An exceedingly interesting chapter of this book is devoted to the minority groups within our borders. "Attainment of complete Americanism is judged principally by the eye and only secondarily by the ear," he says. "The criteria for Americanism are in descending order of importance: appearance, clothes, food, housing, amenities, ideology and language." By these standards, the Negro is obviously the most discriminated against. By length of residence in America and desire to adopt American ways he should be ranked high. But, because he is different in appearance, he cannot compete on equal terms in a white world and must suffer under the capricious and illogical hostility of the dominant group.

Although this book can lay no claim to being a scientific study of American character, it presents a number of penetrating, intuitive observations on the modern American scene. Future historians will probably turn to it for information on present-day America, much as current historians turn to the accounts of earlier British visitors to the U.S. The non-technical reader will find in it much food for thought, but it is to be hoped that he will think rather than believe.

Ralph Linton is Sterling Professor of Anthropology at Yale University

THE AMATEUR

Conducted by Albert G. Ingalls

THIS department for amateur astronomers, thousands of whom have made their own telescopes and glass optical parts, was begun in SCIENTIFIC AMERICAN 20 years ago this month. Since then the amateur telescope making hobby has established a permanent place in American life. The ground covered in these columns has been and will be mainly the description of telescopes and other optical instruments built by its readers, plus improvements on the optical art.

Why has telescope making had so lasting an appeal? For a dual reason. First, it gives outlet to the mechanical instinct, expressed in the form of a telescope, an article greatly worth owning and worthy of some pride because it is not easy to make. Second, the telescope unlocks the way to astronomy, a majestic science that far transcends man's imaginative powers.

It is usual for the potential participant in the amateur astronomical hobby to regard telescope making as little more than preparation, but more often he discovers in it so much hidden fascination, largely in shaping curves on glass, that he makes telescope after telescope of different sizes and types, usually neglecting to use them.

Semerau and his six-inch

From an enthusiastic recruit to amateur telescope making, Walter J. Semerau of Box 64, Alloy, W. Va., comes this:

"Those who helped make the amateur telescope making books possible have caused me to live about two years of my life in complete contentment. I started grinding the mirror for my six-inch reflecting telescope in June and finished in December. I don't believe there is another telescope mirror maker who has derived as much hell and satisfaction from a six-inch hunk of Pyrex. After using up all the wrong methods I reached the right ones after a total of 700 hours' work and finished with a good figure and some small scratches. In doubt, I whipped up a temporary mounting to see whether the mirror would really perform. It performed much better than I had hoped, so I made the permanent mounting shown in the enclosed photograph. The two large setting circles and the saddle by which the tube is fitted to the declination axis were home-made from patterns and castings of duralumin, with the help of your second book *Amateur Telescope Making—Advanced*, which taught me all I needed to know about this accessory art."

Semerau's claim to utmost hell and 700 hours of work is not a record. While about 70 hours for making a first telescope is closer to the average, such an easy outcome robs the maker of much fun in fighting and whipping troubles. This department has on hand for publication descriptions of optically flat precision tools that cost their maker 3,000 hours of work, and of an ultra-fine refracting telescope that accounted for 17,000 hours of enjoyment. There is no limiting length to the enjoyment.

Semerau's telescope is typical amateur work at about the level of the second or third try. Its home-grown design centers on sound conventional ideas, but the details are the maker's own. The casting of the metals is not a "must" nor even the custom, since there are other and simpler approaches to the mounting problem. But it is a nice approach. The two setting circles which appear in the photograph are uncommon in first telescopes and the little finding telescope near the top of the tube is a luxury.

A feature of this telescope is the method of focusing the eyepiece by means of a rack and pinion and thumbscrew which move the entire eyepiece, visible in the illustration, and the small diagonal mirror or prism within the telescope tube. These move as a single unit in a lengthwise direction, guided by v-ways and retaining strips. This method is a little prettier than the more familiar alternative of sliding the eyepiece in and out of an adapting guide in a direction perpendicular to the telescope tube. It is also more pleasing mechanically and often less

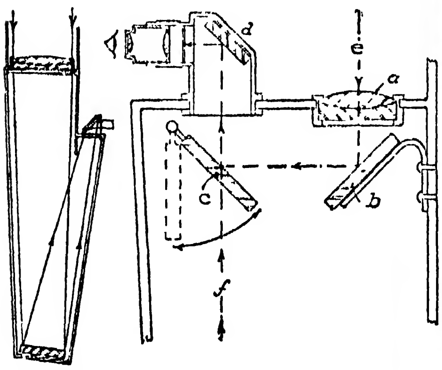
ASTRONOMER

troublesome, as it is less inclined to bind and otherwise perform cantankerously.

If you study the telescope shown in the second photograph you may discover its type but it will be easier to look for the key at the left-hand side of the third picture, drawn by Russell W. Porter. It

Dr. Paul and the euphonium refractor

is a folded refractor made possible by a flat and a prism, and it was built by Dr. Henry Paul of 119 North Broad St., Norwich, N. Y., after a design first proposed by Captain M. A. Ainslie of London. Ainslie's design is embodied in an eight

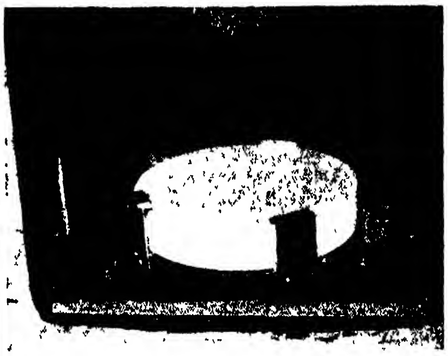


Detail of the euphonium

and a half inch refractor of 120-inch focal length made by H. E. Dall of Luton, Bedfordshire and described by this department in October 1937 and September 1938. Ainslie called it the euphonium

telescope, after the musical instrument of that name, which it resembles.

Unfolded, this would be a six-inch refractor, eight feet long. This is too long to be portable and is therefore not easy to use. The euphonium design brings the eyepiece near the telescope's center of gravity so the observer need move but little in viewing various parts of the sky. It affords normal astronomical inversion,



The flat that folds the refractor

since the stubby eyepiece can be swung through more than 180 degrees to accommodate any desired angle of view for orientation of image (also for comfort). In this respect Captain Ainslie has said it equals or surpasses reflectors, not omitting those with a rotating tube. Dr. Paul has found that his recent version of the euphonium, or jackknife, refractor is very successful.

"I had among my miscellaneous items a perfect six-inch achromat of 94 inches focal length," he writes, "and decided to make a *good* compact telescope. The design appeared in SCIENTIFIC AMERICAN some years ago and I should now like to renew interest in this type, as the problem of mounting a long refractor is sometimes a discouragement. The excellent six-inch achromat and four-inch flat were made by Patrick A. Driscoll of Lima, N. Y., author of several articles in *The Amateur Astronomer*, and I made the instrument in a few days, mainly from insulating Bakelite and aluminum angles.

"The flat (*see cut—Ed.*) is of fused quartz and is precise to a tenth of a wavelength. The eyepiece, which swings more than 180 degrees, should be placed in the corner for convenience to the owner's better, or leading, eye (important). The unoccupied corner may be used for a finder as sketched. In this drawing, *a* is the finder lens (two inches in diameter, 10 inches focal length); *b* is a fixed optical flat; *c* is a hinged, swinging optical flat; *d* is the eyepiece diagonal; *e* is a ray of light to the finder objective and *f* is a ray from the main objective by way of the flat at the bottom of the tube. A knob swings the mirror *c* as shown, instantly making the change from the wide (six-degree) field of the 10X finder to the two thirds of a degree field of the 90X telescope. But the finder alone, with

the 10X, 20X and 30X magnification afforded by different eyepieces, is an interesting and useful instrument for open clusters, the Milky Way, and nebular observation.

"Advantages I find," Paul continues, "are: 1) Compactness: the whole telescope fits crosswise in a car, is easy to handle (note handle on side), and is fully portable. 2) The mounting need be no larger than for a six-inch reflector. 3) Ease of viewing because of widely swinging eyepiece. Disadvantages are: 1) Need of a flat two thirds the diameter of the objective. 2) Some light loss. 3) Heat from the observer's head if the eyepiece is too near the main objective lens; this is why it is placed as shown."

For the three and a half inch, very long focal ratio (*f*/30), special planetary observing type of refractor described with lens specifications by this department in April 1946 by Colonel Lewis of Little Rock, Ark., the euphonium seems to be one good answer.

ONE of the numerous ramifications of telescope making is sundial making, in the course of which the worker becomes familiar with the earth's motions in a way that makes them really sink in to stay. Russell Porter, patron saint of the amateur telescope makers, has found no cure for his sundial itch. His drawing here shows his nineteenth sundial or sun clock since he moved from Vermont to California 20 years ago. After each sundial binge he takes the pledge and promises faithfully to give up the habit, but it always gets out of control and he takes just one more. Like some of its predecessors, this sundial is in a bottle, a pretty large one at that. He writes:

"This is a sun timekeeper that requires no machining or gears, if one is willing to spend something under five dollars for the 11-liter flask (made by Corning).

"It is equatorially mounted, with a thrust bearing at *B* and two pads at *F*. *A* is a single lens that throws the sun's image on the analemma *C* when the flask is turned on its supports.

"The time scale is on a strip of paper *E* pasted on the outside of the sphere. The divisions are five-minute intervals and by interpolation the index at *D* easily permits estimating to single minutes.

"The base is of wood but any kind of base may be used to provide a three-point support. At *B* is a hole drilled through the flask. The stud through it acts as a thrust bearing.

"Another hole is drilled through the flask just under the center of the analemma for a screw to draw down its metal band to a curvature with the lens at its center.

"The flask is remarkably spherical; calipers can detect no departure.

"Warning: Extreme care must be taken to locate accurately *B*, the analemma screw, the time scale and the plane of the central line of the analemma. Fortunately the throat of the flask neck was just large enough to allow insertion of the plate carrying the analemma.

"The sun clock makes an interesting garden ornament but, after playing with it a while, go to your telephone and ask, 'What time is it?'"

Fully to explain this sundial, if perchance the reader lacks a rudimentary education in astronomy, and how to design one for the maker's own unique latitude and longitude, would require several articles, after which the reader still would find himself resorting to the book *Sundials*, by Mayall and Mayall, to learn the fundamentals of all sundial types. If, however, he has made and used an equatorial telescope he is already down to first base in knowing the earth's motions for sundial design. He still may have to give an hour or so to looking into the fact that the earth does not move uniformly in its orbit and to studying the effect of the obliquity of the ecliptic. These are combined in the "equation of time," of which an analemma shaped like the figure eight is a graph. In Porter's sun clock the sun's image falling on that graph automatically allows for the equation of time. Incidentally, the graph can also be made a calendar.

Porter's nineteenth sundial

To make the holes in the flask calls only for a hand drill, an inch of small tubing in its chuck, a few dabs of wet abrasive grains and five minutes' elbow grease.

The underlying motivation behind sundialing isn't to tell the time, though the editor of this department has one at his summer cabin and really uses it, in the happy absence of a radio, to set his dollar watch. It brings visitors up with astonished surprise to be told the sundial time and to find that it agrees with their watches often to seconds. The main motivation in sundialing therefore is intellectual—call it scientific vanity. Your dial's correct functioning shows you that you know a little positional astronomy and gives you a feeling of superiority over people who own department-store sundials and don't know why they can't keep time.

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FIFTY CENTS

June 1948

SAVE A CHILD—SAVE THE FUTURE

Photo by Roman Vishniac

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LETTERS

Sirs:

I should like, if I may, to express my gratitude for the long and detailed review which Professor Linton has given to my book, *The American People*, and for the confirmatory evidence he provides for a couple of the hypotheses therein. I am gratified that an anthropologist of Professor Linton's eminence should pay the book so much detailed attention.

He does however include a couple of criticisms which I should appreciate the chance of discussing. The more important point is the question of the validity of this type of analysis; but Professor Linton also devotes quite a lot of space to deducing, doubtless by the most scientific principles, the contacts I have had in the United States. He writes: "It appears that Gorer's American contacts have been almost exclusively with the members of two groups: middle-aged clubwomen . . . and the semi-Bohemian intelligentsia of New York and vicinity." As a matter of fact, Professor Linton has had a number of opportunities of exercising his scientific observation of my contacts at meetings of the American Anthropological Association, and smaller anthropological meetings in New York and New Haven; and I confess I am curious to know under which of these two categories he includes our professional colleagues. More seriously, I somewhat resent the slur on the generosity and hospitality of hundreds of Americans in every walk of life and every part of the United States who have entertained me and made me feel welcome; and I should not have thought it needed very abstruse calculations to understand why I did not fill several pages with the names and addresses of my hosts.

On the more technical level, Professor Linton makes his chief objection on the ground that "no statistical methods were employed at any stage in the study." It is true that I made no studies of distribution myself; but I did make fairly consistent use of the available statistical studies, as a background to my conclusions, and have referred to most of them in the preface or the footnotes. Because I was writing in the first place for an unspecialized British audience. I only included the most essential figures in my text, for such an audience is repelled by rows of figures and statistical tables. Interested specialists can easily discover the confirmatory figures by consulting the sources I quote, from *Statistical Abstracts* through such important sociological studies as Gunnar Myrdal's *American Dilemma* or the *Yankee City* series of Professor Lloyd Warner and his associates. to the ten years of the *Fortune* public opinion poll. In his reproofs, Professor Linton does not cite any authorities whom I should have consulted, and did not.

On a great number of the subjects with which I attempted to deal, statistical information is unfortunately not yet available. In the case of American childhood training, for example, I know of no studies of distribution; such excellent studies of child training and development in the contemporary United States as those of Drs. Gesell and Ilg present a wealth of detail from which a pattern can be abstracted, but no statistical evidence of the distribution of the customs they describe. I agree with Professor Linton that ideally all such statements should be backed by statistics; but the man who has reconstituted (from what slender sources!) the culture of the Comanche three centuries ago, and described the culture of the Marquesans on the basis of casual observations made nearly two decades earlier when he was devoting his attention to artifacts and after the society he was describing had almost completely disintegrated- such a man must surely acknowledge that the scientific ideals of anthropology cannot always be attained even in the primitive field, not even by one of the most distinguished and most lucid of living anthropologists. Admittedly, American culture is infinitely more complex than Comanche or Marquesan; but if the same criteria are applied to all three studies, where exactly are Professor Linton's statistics?

Rather than indulge in this type of mutual recrimination, I should prefer to associate myself as emphatically as possible with Professor Linton's conclusion, in which he urges the "non-technical reader" to "think rather than believe." That would be, for me, the ideal result of my book. I present a series of interrelated hypotheses, nearly all of which are susceptible to statistical proof, disproof or modification; if the book succeeds in provoking researches, I shall feel that I have been justified in rushing in where professors fear to tread.

London GEOFFREY GORER

Sirs:

I have read the new SCIENTIFIC AMERICAN from cover to cover, and congratulate you most heartily upon it. The articles are on a high level -reached elsewhere, I think, only by the English magazine *Endeavour*. Keep this up and you will fill a badly needed place in this country. The only minor criticism that I have is that some of the illustrations in Professor Whipple's paper are a bit modernistic.

HENRY NORRIS RUSSELL

Princeton, N. J.

● The Board of Editors extends its thanks to Henry Norris Russell, whose articles on astronomy for many years enhanced the pages of the old SCIENTIFIC AMERICAN, and to other readers who have expressed their good wishes to the new SCIENTIFIC AMERICAN.

50 AND 100 YEARS AGO

JUNE 1898. "Prof. Dewar has recently liquefied hydrogen, which is an unprecedented feat. This invention was announced by cable to The New York Sun on May 11, and now fuller accounts of his experiments have been published. There is already controversy as to where the credit belongs for first bringing this element into control. The Polish scientist Olszewski forestalled the discovery a year or two ago by accurately determining the critical temperature and boiling point of hydrogen, but he did not succeed in reducing the gas to a liquid form in a really practical way, so that it could be examined and its properties tested."

"Undoubtedly the chief center of interest in the Spanish-American war lies just at present in the harbor of Santiago de Cuba, and, judging from present indications, this is likely to be the seat of the most active and important operations for some time to come. The rumors of last week, to the effect that Admiral Cervera's fleet was "bottled up"- to use the pet phrase of the day—by our fleet were confirmed by an official dispatch from Commodore Schley. The fleet was identified on Sunday, May 29, by the unprotected cruiser "Marblehead," which, acting under the orders of Commodore Schley, ran in close to the Morro Castle, and steamed past the entrance to the harbor in a westerly direction. Her officers had a good view of the interior of the harbor as far as Punta Gorda."

"The Governor of Massachusetts has signed a bill which substitutes electricity for hanging as the method to be followed by that State hereafter in putting to death condemned criminals."

"One of the questions periodically brought forth for discussion is the advisability of establishing a Department of Science, in which all of the scientific work of the general government shall be concentrated under one chief. It is said that each of our larger bureaus now prosecuting scientific inquiries has a director with an executive corps consisting of a chief clerk, private secretary and disbursing officer; that many have a special library, with a librarian and assistants; that not a few sustain laboratories with similar names if not identical functions, and that each is deprived of the support of the others, while all lack the strength that union alone can give. The corrective suggested for avoiding duplication of directors, chief clerks, librarians, etc., and the remedy for the dispersion of energy now volatilizing in so many workshops is to consolidate, to have one great Department of Science; in short, to centralize."

"A method of centrifugal casting has been recently introduced and described by which castings similar to the ordinary chilled castings can be produced in the following way: The mould is made to rotate, when a hard steel is poured in, which flies to the sides; soft steel is then poured into the hollow center, with the result that the casting produced has a soft core and a hard face."

"It has been observed in several instances that X rays have a peculiar action on the skin, causing it to get red and sometimes black, and also causing the hair to fall out."

"It is always the unexpected that happens. In November, 1896, a Spanish periodical, La Ilustracion Española y Americana, in an article about the capital of the Philippines, made the following statement: 'Even the strongest army would fail to capture Manila from the land, but the city has no protection of any importance against modern men-of-war.' The Spaniards did not consider until quite recently the possibility of an attack by a hostile fleet, and the hasty preparations made when such a contingency arose were not sufficient to remedy the inferiority of these fortifications."

JUNE 1848. "The America, the new steamer of the Cunard line, arrived at Boston on Tuesday evening last from Liverpool, making the passage in 10 days and 8 hours. She made the passage to Halifax in 8 days and 20 hours and to Boston in 10 days, having been detained 8 hours in the fog. This is the quickest passage that ever has been made to America."

"Miss Maria Mitchell, of Nantucket, discoverer of the Comet which bears her name, was unanimously elected an honorary member of the American Academy of Arts and Sciences, at their last general meeting. We believe that this is the first time such an honor has been conferred on any lady in this country."

"Two amputations were performed last week at the Bellevue Hospital of this City, the one that of an arm by Dr. Cox, one of the Assistant physicians; and the other, that of part of the foot, by Dr. Childs one of the visiting Surgeons. In both cases the patients were first rendered insensible to pain by the use of Chloroform diluted with four times its bulk of sulphuric ether, with which a sponge was moistened and held to the nostrils by a Resident Physician, Dr. Reese, who has had extensive experience in the use of both chloroform and ether, although this was the first time these agents had been used here in combination."

"The Electro Magnetic ore separator is a machine invented by Ransom Cook, Esq. late Superintendent of the Clinton County State Prison in this State, and employed for the separation of the magnetic ore at the mines in that place. The principle of this invention consists in charging successively by a battery different rows of magnets on a revolving cylinder, so that the magnets will lift magnetic ore from an endless web as it passes under the cylinder."

"The garden of the Empress of Russia on the island of Yelaguine has conservatories of glass which are upwards of two thousand feet in length. Eighteen columns support the roof; it is nearly eighty feet high, and upwards of one hundred in width."

"The stupendous project of uniting the waters of the broad Pacific with those of the Atlantic by a Railroad to the Bay of San Francisco, California, is one of great magnitude, but it is one which will, and must yet be carried into execution. A railroad will yet connect New York with San Francisco, and a line of steam vessels will cross the Pacific regularly, keeping up a continual communication with China and the United States."

"A remarkable telegraph race occurred in this city last week, when the Whig National Convention was in session in Philadelphia. The Jersey City wires were monopolized by the Whig Press, and our other papers had to bite their thumbs for news. But science was not to be baffled for news by a monopoly, so they dispatched a message via Albany and away round by Buffalo, Cleaveland, Cincinnati and Pittsburg, to Philadelphia. In fifteen minutes, over the same route, an answer was returned announcing the result of the second balloting for candidates for the Presidency. It is just as easy to stop the lightning as the enterprise of some of our papers."

THE COVER

The painting on the cover shows the fragments of baked clay that remain of the law code of Lipit-Ishtar (*page 44*), a Sumerian king who reigned in the nineteenth century B.C. Around the fragments are implements used in their translation by the archaeologist.

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SCIENTIFIC AMERICAN
Established 1845

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My ~~greatest~~ thanks for the parcel you have sent to me with CARE.
I already received two
I always
yesterday we have received your recent "CARE" package. Once more the unpacking of these very useful foods has been a joy
Par cette lettre je vous remercie d'un nouveau colis que vous avez eu la bonté de m'envoyer
All the wonderful foods in your CARE package are still scarce here. It is impossible for you to imagine how des-
It's MORE FOOD for LESS MONEY
Send
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Food Packages Abroad...$10.
INSURED · GUARANTEED DELIVERY
DUTY FREE · RATION FREE
NON-PROFIT · GOVERNMENT APPROVED
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BAKERS COCOA
SUN-MAID RAISINS
BEEF LOAF
PAR AVION
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SCIENTIFIC AMERICAN

JUNE 1948 VOL. 178, NO. 6

THE NATIONAL SCIENCE FOUNDATION

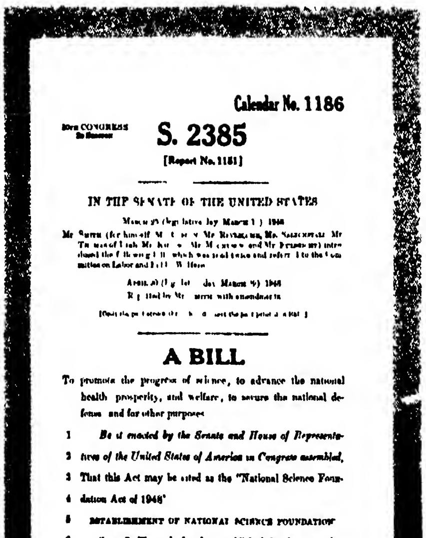
Its momentous responsibility will be to assist the fundamental research which is essential to human progress

by Alfred Winslow Jones

ON MAY 5 the Senate passed, by a unanimous voice vote, the long-awaited legislation in behalf of basic science. By the time this article appears in print the House may have acted and the President may have signed the bill. If so, there will be set up in Washington a National Science Foundation with unique responsibilities and powers. Almost everyone concerned will be happy about the outcome of a long, irksome debate, and reasonably satisfied with the compromises reached on the many issues that had to be resolved to bring the Foundation into being.

The Foundation will do its job mainly by making research grants and loans to non-profit institutions and by giving scholarships and fellowships to individuals. It will support research for the armed services after consulting with the Secretary of Defense. It may set up commissions for special jobs and may establish divisions for dealing permanently with particular branches of science. The chief emphasis is on the natural sciences, but "other sciences" also may be assisted, which is as near as the present legislation comes to including the social sciences. Here, almost surely, is a realm for ardent future discussion within the Foundation.

The spacious powers given to the Foundation are to be further defined and exercised by a 24-man board of persons "eminent in the fields of the basic sciences, medical science, engineering, education, or public affairs," serving part-time and appointed by the President. To execute


Calendar No. 1186

80th CONGRESS 2d Session

S. 2385

[Report No. 1151]

IN THE SENATE OF THE UNITED STATES

A BILL

To promote the progress of science, to advance the national health, prosperity, and welfare, to secure the national defense, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "National Science Foundation Act of 1948".

ESTABLISHMENT OF NATIONAL SCIENCE FOUNDATION

SEC. 2. There is hereby established in the executive branch of the Government an independent agency to be

SENATE BILL, embodying changes which caused 1947 veto, passed May 5.

the policies and decisions of the board, the Foundation will have a full-time $15,000-a-year director, also appointed by the President. According to the present budget figures, the Foundation will have $20 million to spend during its first year. As it learns how to spend money, its appropriations should grow from year to year, reaching a figure that Presidential adviser John R. Steelman projects as $100 million after 10 years.

U. S. scientists are almost unanimous about the need for large-scale Federal aid to basic research. Without it American scientific work would move more and more toward the periphery of application, leaving a less and less adequate ratio of basic work going on at the center—except, for a time, under military auspices. The ultimate result might be a hollow shell of mere technology, followed by the decline of technology itself.

The reasons are familiar enough. The practical Yankee genius has always tended toward the making of tools and the mass production of goods, at the expense of the essentially speculative enterprise of basic or pure science. The main sponsors of American science have been industry, the government, the universities and the foundations. Industry, by and large, wants practical results for the money it spends. The people in charge of government agencies and the legislators who make the appropriations have followed the bent of industry. All of the agencies listed on the next page have sponsored chiefly applied science. This leaves the universities and foundations as the main traditional promoters of basic research. They have done the best they could, but their funds have been limited and the pull upon them by industry for applied studies has been strong.

As a consequence we have been notoriously dependent on European science for basic findings and even for development work, since Europeans, supported by their governments, have been by far the more

GOVERNMENT AGENCIES AND LABORATORIES IN SCIENCE

Department of Agriculture

Office of Experiment Stations
Bureau of Animal Industry
Bureau of Dairy Industry
Bureau of Plant Industry, Soils and Agricultural Engineering
Bureau of Entomology and Plant Quarantine
Bureau of Human Nutrition and Home Economics
Bureau of Agricultural and Industrial Chemistry
Agricultural Research Center, Beltsville, Md.
Forest Service
Soil Conservation Service
Production and Marketing Administration
Farm Credit Administration

Department of Commerce

National Bureau of Standards
Civil Aeronautics Administration
Weather Bureau
Coast and Geodetic Survey

Department of the Interior

Geological Survey
Bureau of Mines
Fish and Wildlife Service
Bureau of Reclamation

Navy

Office of Naval Research
 Planning Division
 Naval Research Laboratory
 Special Devices Center
Bureau of Aeronautics
Bureau of Yards and Docks
Bureau of Medicine & Surgery
Bureau of Ships
 David W. Taylor Model Basin
 Navy Electronics Laboratory
Bureau of Ordnance
 Naval Ordnance Laboratory
 Naval Ordnance Test Station

Army

Army Technical Services
 Quartermaster
 Signal Corps
 Ordnance
 Chemical
 Engineers
 Medical
 Transportation

Air Force

Wright Field
Patterson Field
Cambridge Field Station
Ladd Field
Muroc Army Air Base
Watson Laboratories
Alamogordo Army Air Field
Boca Raton Army Air Field
Eglin Field
Olmsted Field

Federal Security Agency

National Institute of Health
U. S. Public Health Service
Food and Drug Administration

National Advisory Committee for Aeronautics

Langley Memorial Aeronautical Laboratory
Ames Aeronautical Laboratory
Flight Propulsion Research Laboratory

The Smithsonian Institution

Research Division

Atomic Energy Commission

Research Division

Federal Works Agency

Public Roads Administration

Federal Communications Commission

Engineering Department

Federal Power Commission

Bureau of Power

Veterans Administration

Medical Research Division

Treasury Department

Bureau of Printing and Engraving
Bureau of the Mint
Coast Guard

Federal Loan Agency

Office of Rubber Reserve

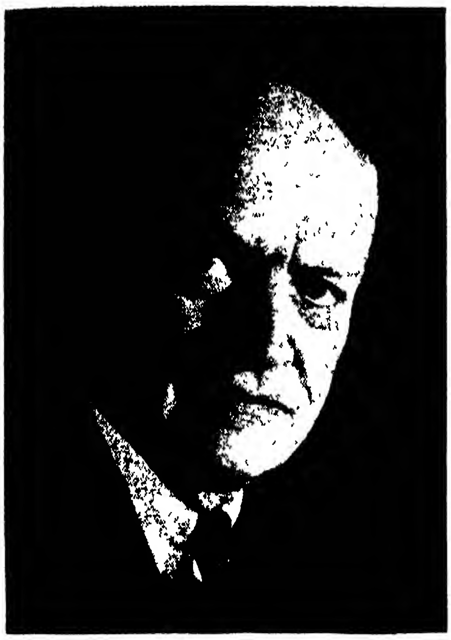
adventurous pioneers at the frontier of knowledge. To cite one of many illustrations: Of the 149 Nobel prize winners in physics, chemistry and medicine since 1901, 123 were born and received all their early training in Europe, and only 22 were U. S.-born and trained. (Two awards went to Canada, and one each to India and Argentina.) As between Europe and the U. S., this is out of all proportion to national wealth and the application of scientific findings.

The war has obviously left Europe unable to maintain its old contributions to the international fund of pure science. If private American efforts could fill the gap, there would be no problem, but actually they are failing to maintain even the traditional insecure position of pure science in this country. In 1929 the funds laid out for scientific research by universities and foundations (the most accurate measure we have for the support of basic research) amounted to only 15 per cent of a national research budget of about $170 million. By 1939 the ratio had shrunk to 10 per cent and, although the dollar total of university and foundation research funds had increased to $35 million, a substantial part of this outlay included income from research contracts with industrial concerns, which represented a diversion from pure to applied science.

More recently universities and foundations have suffered from lower yields on their investments and from higher costs of research, and the universities have had more students and hence greater deficits. During the war the nation's proportion of development expenditures, other than those of industry and the Federal government, shrank to 4 per cent; it now stands at about 8 per cent. Of the $2.5 million which Columbia University, for example, had this year for physical research, only $16,000 was from University funds, the rest coming from the government, most of it from the Atomic Energy Commission.

JUST AS critical is the manpower shortage. Curtailment of education during the war cut the maturation of new scientists by half. The grievous loss may be estimated as some 20,000 graduates, including 3,000 doctors of science. Those who have been graduated are under an almost irresistible pull from industry. If it were not for a new interest in basic science on the part of the armed services, the plight of fundamental research would be cause for even greater alarm.

The war itself brought an almost total inhibition of basic research in the U. S. Virtually to a man, the scientists of the U. S. were brigaded under the command of the Office of Scientific Research and Development for the most massive campaign of applied research ever organized. The more than 2,000 projects to which they were assigned spent $300 million directly and guided the spending of hundreds of millions more. Two of the



SENATE BILL was introduced by Senator H. Alexander Smith of New Jersey, who also was its 1947 sponsor.

projects, the atomic bomb and radar, began as hopes and developed into billion-dollar enterprises by the end of the war.

The stupendous achievements of the OSRD shortened the war and saved countless lives, but its aftereffects must now be reckoned with. During the war the armed services received from the scientists imaginative and efficient new devices and techniques useful in almost every branch of operations. The war, therefore, endeared science to the military mind and even won it over to the need for basic research. The military is now determined that there shall be no postwar

HOUSE BILL for the Foundation was sponsored by Representative Charles A. Wolverton, of New Jersey.

divorce. Under military auspices, science in general, and even some branches of pure science, are now being maintained in a style to which they have never before been accustomed.

The best measure of the government's and the military's present involvement in scientific work is the Federal budget estimate for research for the fiscal year beginning July 1. The grand total is likely to be about $825 million, an increase of almost 25 per cent over this year and 15 times as much as was spent in any year before the war. Of this staggering sum, over $650 million is for the Army, Navy, Air Force and for the military work of the Atomic Energy Commission and the National Advisory Committee for Aeronautics.

A rough indication of the proportion of government funds which is being allocated to pure and applied research, respectively, was given in the so-called Steelman report, issued by the President's Scientific Research Board, John R. Steelman, chairman. Analyzing research expenditures in the fiscal year that ended in mid-1947, the report estimated that some $570 million out of a total of $625 million went for applied and developmental studies. For the armed services the figures were $465 million out of $500 million. Of the $100 million spent by the four civilian agencies with the largest research budgets—Agriculture, Commerce, Interior and the NACA—about $85 million was spent on nonbasic work, chiefly background research, that is, fact-gathering, compiling, surveying and the like.

Since the end of the war scientists have been actively debating the role of the military in the scientific affairs of the country. Some are contented enough, and see no serious threat to the integrity of their work. Others are extremely unhappy—alarmed about the fatal blight of secrecy, about dismissals on mere suspicion of unreliability, about the inevitably limited objectives of the Army and Navy. They are afraid of the intrusion of others into their work and afraid that military-sponsored basic science will be cut off in favor of applied efforts when the now copious funds may be curtailed—at a time when the universities will have become dependent on military contracts.

Most scientists are grateful for the stopgap aid they have had, but many are now eager for other sponsorship. The body of scientific opinion appears to be opposed to an entire new department with a Secretary of Science (as was once proposed) but in favor of a civilian, independent agency. Specifically, through the National Science Foundation they look for a good, solid compromise between the old days of freedom and poverty and the wartime binge of regimentation and inexhaustible funds.

The new agency has been at least three years in the making. The New Deal, the war and the work of the OSRD under Vannevar Bush provided the impulse. Then developed a serious struggle over important details. In July of 1945, the creation of a "National Research Foundation" was urged by Bush in his report, "Science, the Endless Frontier," written in answer to the request of Franklin Roosevelt. The following October, Senate committee hearings began on three bills. One of the two important ones, the Magnusson bill, followed faithfully the recommendations of the Bush report and put control of the Foundation in the hands of a part-time board appointed by the President. The Kilgore bill incorporated additional ideas by providing for strict patent controls in the interest of the government and in giving control and responsibility to a presidentially appointed director, advised by a board of scientists. This matter of administration became the most hotly contested point in the subsequent debate. In July of 1946, a compromise Kilgore-Magnusson bill (S. 1850) passed the Senate, but was killed in the House. The compromise, which seemed to represent a majority view among scientists, leaned too far toward the Kilgore position to be acceptable to the Bush people.

Last year Senator H. Alexander Smith of New Jersey introduced S. 526, which passed both the Senate and the House. This bill leaned just as far toward the Bush position, but was supported by many scientists who had come to feel that it was about the best they could get. The Smith bill was regretfully vetoed by the President on the ground that it set up an impractical type of administration with the power in the hands of a board rather than a single director.

The 1948 Smith bill (S. 2385), which will pass in the closing days of the 80th Congress—or, failing that, the similar bill that clearly should be made a law in 1949—is a reasonable enough compromise, though it is still administratively not what the President hoped to get. The chief executive officer of the National Science Foundation will be appointed by the President, to be sure, but he will be fully governed and guided by the Foundation's legislative body, its 24-man board of eminent scientists and others. To this board is left the final decision on most of the controversial matters that have been fought over for the last three years.

THE FOUNDATION will decide just how wide a geographical distribution to give its grants and contracts. It will decide to what extent it can hold as public property patents resulting from work in which it takes part, and how far it will have to go in allowing patent rights to those with whom it makes contracts. It will decide whether or not to set up its own executive committee. It will prescribe its own rules and regulations. It may acquire real and personal property. It may receive funds donated by others. It may publish freely in the field of science.

The Foundation must clear security matters with the Secretary of Defense, and

it may not go into atomic research without the permission of the Atomic Energy Commission. It is authorized to cooperate in international scientific research but any such activity "shall be exercised in such a manner as is consistent with the foreign policy objectives of the United States as determined by the Secretary of State, after consultation with the Director."

The greatest of the Foundation's considerable powers is that of deciding just what jobs to tackle. Certain obvious divisions—1) Medical Research 2) Mathematical, Physical and Engineering Sciences, 3) Biological Sciences, and 4) Scientific Personnel and Education—are suggested by Congress but even these are not insisted upon.

With the probable passage of this legislation, the scene shifts. The Foundation itself now becomes the focus of arguments as to what it should do and how it should do it. The most vital and difficult single issue will be whether or not the Foundation shall undertake work in the field of social science.

Such a venture is admittedly fraught with difficulties. The social sciences differ from the physical and biological sciences more than the latter differ from each other. By the accepted standards of scientific work, the social sciences are less mature. Experimentation in them is usually impossible. Those who operate with social data are forced into more complex and higher abstractions and into many areas where measurement is impossible. Social science has ill-defined limits. At the end of its spectrum farthest from the biological sciences, its lines tend to blur into an area (from the scientific point of view) of mere heat: the warm, disorderly, ethically supercharged humanities.

A more serious difficulty stems from the deep and stubborn cleavage between pure and applied effort in social science. As James Bryant Conant has pointed out there was a time when such a condition did not constitute a detriment to any branch of science. Until perhaps 100 years ago, science was almost entirely pure, and technology was in another realm. But now, the sphere of science has become so completely integrated that a scientific effort which remains endlessly pure, with no eventual application, is not thought of as science at all but as some sort of recondite, priestly discourse.

TO A DEGREE, this is what has happened to social science. Frightened away from the periphery of application by the fierce heat of controversy that is engendered there by conflict of interests, some "social scientists" take refuge in "pure" effort that is not nor ever will be, called into practical play. Many an able social scientist spends his time endlessly gathering facts which are not really gathered to be used because their use would get the user into trouble.

ORGANIZATION of the Foundation is depicted on the basis of the Senate bill introduced by Senator Smith. Its power is principally in the hands of the 24-man board, although the President appoints the director. Many of the organizational details have been left to the discretion of the Board.

Pure and applied social science can serve special interests admirably, but the National Science Foundation is being set up to serve the general interest. Can it do so in the field of social science? The difficulties will loom so large that it will take a board of 24 (or at least a majority of 13) brave men to make the effort.

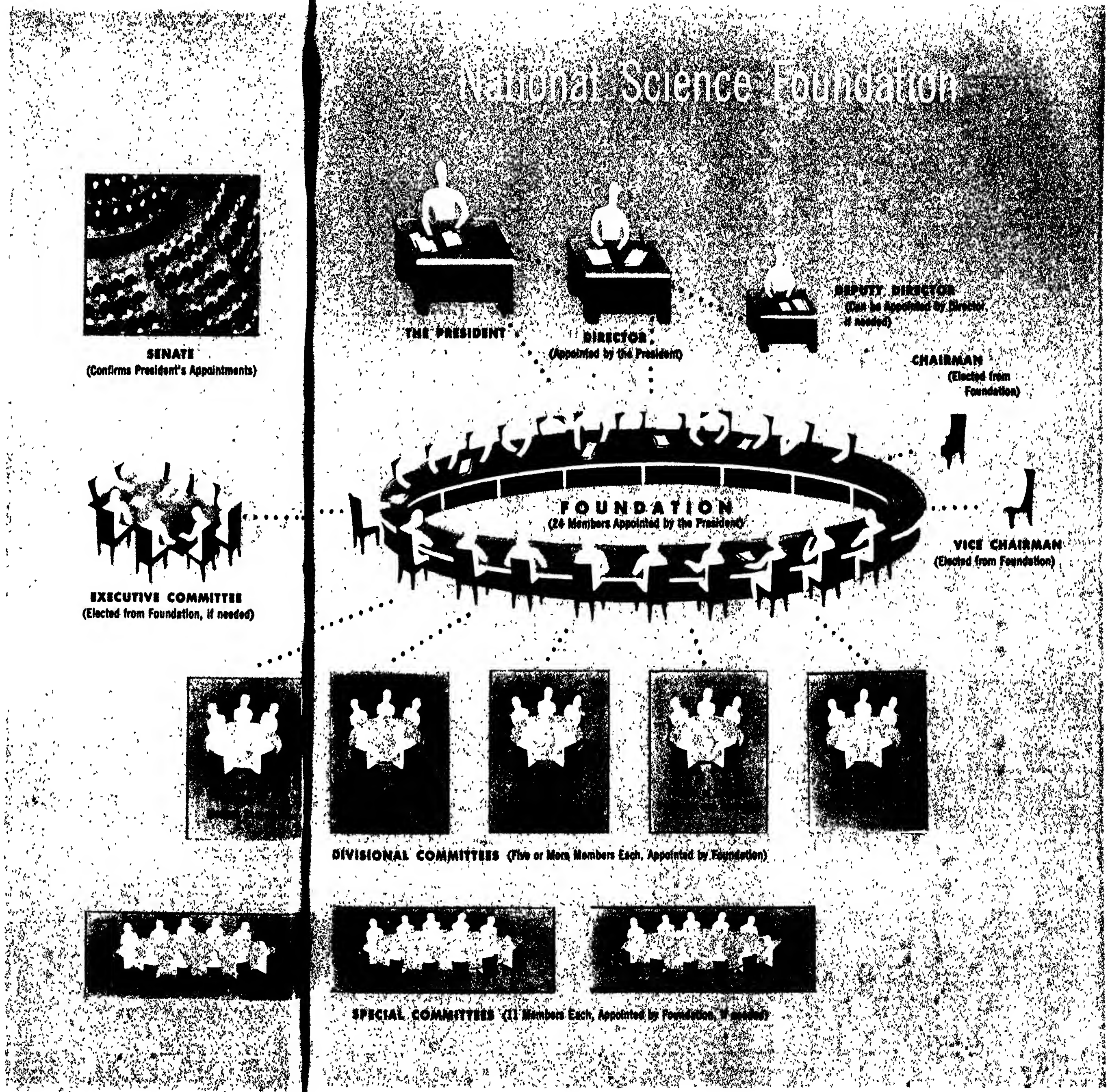
Yet none of this is to deny the scientific and human potential of social science nor its great and urgent need. True, the direction of effort in the social sciences must differ sharply from that taken in the natural sciences. In the latter, the emphasis will rightly be on pure or basic work, since the spontaneous drift is away from it. In the social sciences, more attention will have to be given to practical problem-solving.

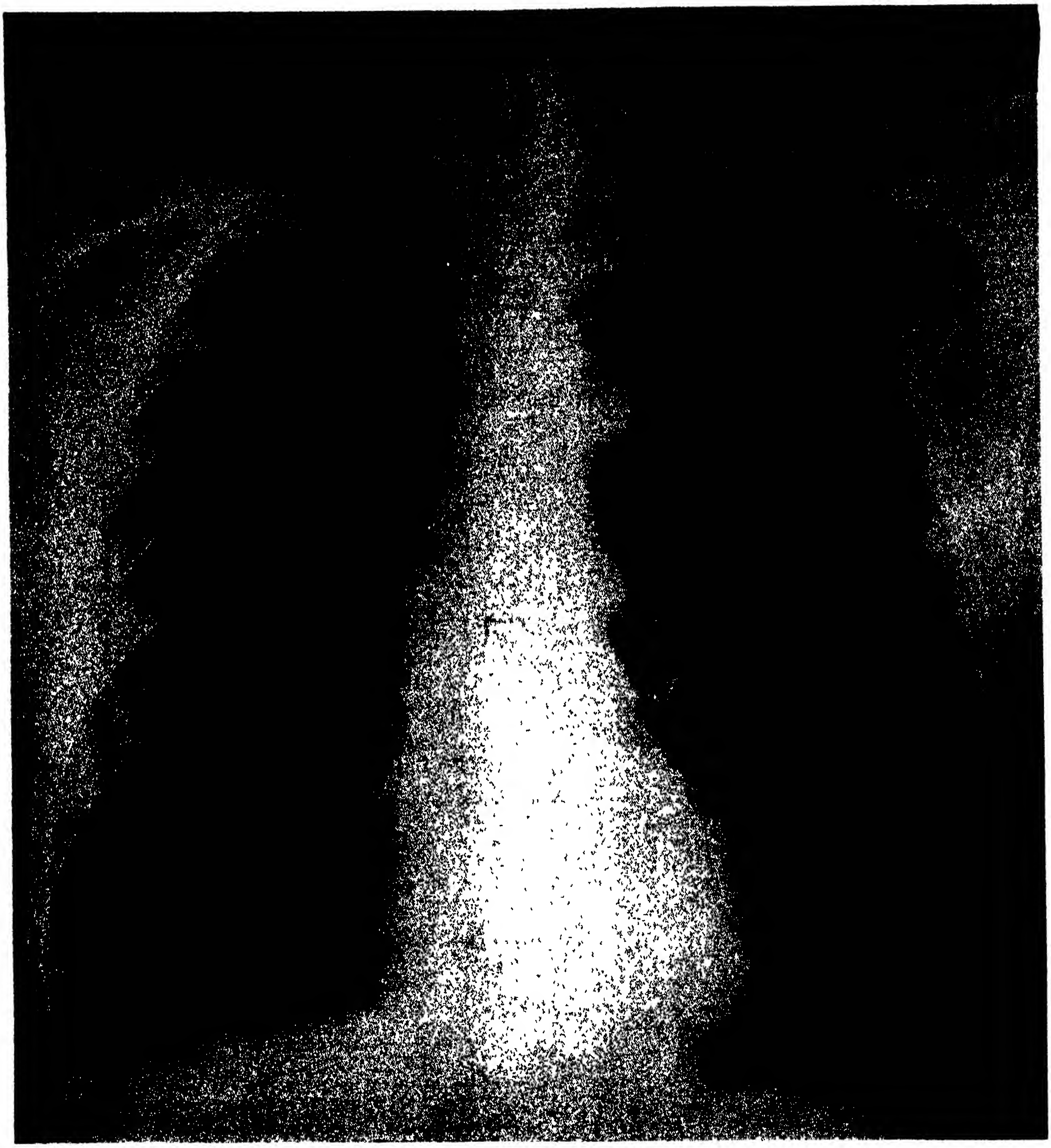
Some things the Foundation can do easily. It can help develop the tools of social science, such as statistics and semantics. It can go into certain fields that seem relatively factual and remote from the battle, such as anthropology and demography. It could look at such problems as labor mobility, which would have to be gone into simultaneously in all parts of the country and would cost some $800,000. It could study the adjustment of individuals to handicaps and illness. It could look at the procedures of that big and influential industry, public opinion polling: its sampling methods, panel studies, interviewer bias, and the like.

Since none of this promises to solve basic social and economic problems, the Foundation could, once its formula is worked out and once it has the necessary experience, go after the things that really matter.

Science is increasingly becoming a part of our culture, and general Federal aid is hardly more than a recognition of that fact. Science has given us much of what we have of material wealth, and is certain to give us more. But it is now generally recognized that material progress brings the exaggeration of social and economic problems while at the same time it makes their solution possible. Will the coming National Science Foundation try to realize that potential, or will it be satisfied to act merely as one more vitally needed agency for still more material progress? Here the President, who appoints the board of the Foundation, and the board itself will face a major decision.

Alfred Winslow Jones is a writer on social science





LUNG LESIONS revealed in this X-ray photograph may have been produced either by tuberculosis or by histoplasmosis. Tuberculin test and histoplasmin skin test, however, may also be called into play. Symptoms of "acute", or non-fatal, form of histoplasmosis are rather similar to those of grippe, but sometimes the disease passes without manifestation worthy of notice.

HISTOPLASMOSIS: THE UNKNOWN INFECTION

The mild form of a fatal fungus disease appears to be spreading in the U. S. Its lesions are much like those of tuberculosis, complicating diagnosis

by Martin Gumpert

IN 1944 a five-month-old infant was admitted to the pediatric hospital of Vanderbilt University in Nashville, Tenn., with a puzzling illness. Its symptoms, which included fever, loss of appetite, and anemia, were those of many common childhood ailments; yet it was evident that this child was uncommonly sick. Dr. Amos Christie of the University staff suspected that its ailment was an obscure fungus disease called histoplasmosis. A skin test, and later the discovery of the fungus in the infant's blood, proved his diagnosis correct. No treatment is known for this disease, and the child died.

Up to that time, the medical literature had recorded only 80 cases of histoplasmosis, all of them fatal. The disease was thought to be extremely rare; even its name was unknown to most physicians. Dr. Christie, a pediatrician interested in the study of fungus infections, availed himself of the opportunity to investigate this little-known disorder. The skin test for histoplasmosis, which had only recently been developed, offered a handy method. He gave the test to the parents of the afflicted child. Although apparently healthy, both parents exhibited positive reactions to the test, indicating that they were infected with the fungus or had been at some time in the past. The scientist went on to apply the same test to several groups of children and found that a surprisingly large percentage of them were similarly infected, although many showed no symptoms of illness. Dr. Christie concluded that there must be a benign form of the disease of which doctors had been unaware, and that histoplasmosis was probably more widespread than anyone had suspected.

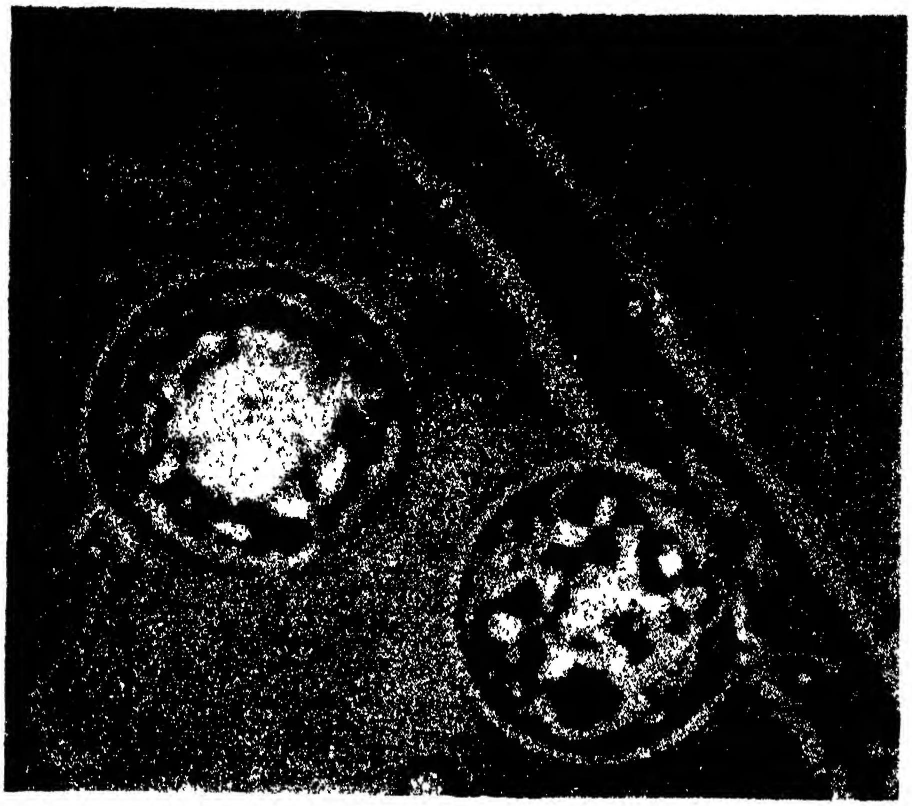
His suspicion was soon confirmed. Early in 1945 he received a visit from Dr. Carroll E. Palmer of the U. S. Public Health Service. Dr. Palmer examined closely some X-ray pictures that Dr. Christie had made of his suspected histoplasmosis patients. They showed calcifications of the lungs like those in tuberculosis. But the patients did not have tuberculosis; they had reacted negatively to tuberculin tests. Startled by the resemblance of these lesions to those of tuberculosis, Dr. Palmer decided to make a large-scale national survey. He gave the histoplasmin skin test to thousands of student nurses in 65 nursing schools distributed in various sections of the U. S. The results were astonishing: almost one fourth of all the students reacted positively to the test. The incidence of the disease varied by geographic areas. It appeared to be highest in the East Central states. In Kansas City, Mo., for example, 62 per cent of the persons examined had positive reactions.

Since it seemed reasonable to assume that a positive reaction to the test was good evidence of previous infection with the histoplasmosis fungus or a closely related organism, Dr. Palmer decided that this disease, formerly thought so rare, must be fairly common. Later studies have supported his view. As is often the case when a disease becomes more widely recognized, there has been a sudden increase in the number of reported cases of histoplasmosis. It is now thought that millions of Americans are afflicted with this infection. And there is good reason to believe that a very high proportion of patients who have been diagnosed as tubercular because of lung calcifications may have histoplasmosis instead.

The high rate of mortality in diagnosed cases of histoplasmosis indicates the dangerous potentialities of this disease. It appears to exist in two forms: a so-called "acute" type, which is the mild form discovered by Dr. Christie, and a "chronic" type, which is highly fatal. The "acute" infection passes quickly and in most cases is unrecognized, since it either shows generalized symptoms like those of acute grippe or goes through a subclinical course that is not noticed at all, as in many of Dr. Christie's cases. The "chronic" type —the classical form of the disease—has been recognized only since the beginning of this century. It is sometimes known as Darling's Disease, after the American physician Dr. Samuel T. Darling, who discovered it. It is still difficult to diagnose, as mentioned earlier, because its symptoms do not distinguish it sufficiently from other diseases. The most common symptoms are fever, anemia, enlargement of the liver and spleen, swelling of lymph glands, loss of appetite and weight, ulcerations of the mucous membrane of the mouth, especially of the tongue, and a diminution in the number of white blood cells.

THE history of this baffling infection demonstrates the flexibility of mind demanded by scientific investigation and the necessarily tentative nature of all conclusions in science. Histoplasmosis confused medical scientists from the beginning because it was so much like other diseases. In 1906 Dr. Darling, then head of the Ancon Hospital in the Panama Canal Zone, observed among his patients a few cases of what seemed to be kala-azar, the "black disease" or "dumdum fever," which was then ravaging India. This Asiatic disease, which is caused by a parasitic protozoon of the Leishmania group, had not previously been seen in the Western hemisphere. But Dr. Darling's patients had two characteristic symptoms of kala-azar—enlargement of the spleen and a decrease of the white blood cells. The patients died, and in autopsies Dr. Darling found in their organs an organism resembling the Leishmania of kala-azar. He called this parasite, which he believed to be a protozoon, *Histoplasma capsulatum*.

By 1912 further study had led to the conclusion that the histoplasma organism was not a protozoon but a fungus. It was not until 1934, however, that a pure culture of Histoplasma capsulatum was obtained, by Dr. W. A. De Monbreun of Vanderbilt University. Now able to produce the disease experimentally in animals, he established that its agent was a



ORGANISM which causes histoplasmosis is the fungus *Histoplasma capsulatum.* When it invades the body it grows in the reticulo-endothelial system, which includes organs such as the spleen and liver. There its colonies become encapsulated much as those of the tuberculosis bacillus.

GROWING IN AIR on a culture dish, H. capsulatum sends out tendrils bearing spores. The route by which the disease spreads is not known but investigators think it may be borne through the air in droplets. This theory is enhanced by the fact that the disease often attacks the lungs.

fungus which is classified as belonging to the genus Histoplasma of the family Coccidioides.

This was a discovery of far-reaching significance. It gave proof of what was essentially an unknown type of disease. Fungus infections of the skin, such as ringworm and athlete's foot, were well known, but little attention had been given previously to systemic fungus infections, which are generally dangerous and often fatal. Studies which followed left no doubt that general fungus infections are much more frequent than had been supposed.

A DISEASE closely related to histoplasmosis has been known for some years. It is coccidioidomycosis, also known as San Joaquin Valley Fever or Desert Fever. It is endemic in certain districts of California and Arizona. Its agent is a fungus of the same family as Histoplasma. Like histoplasmosis, this disease has a relatively harmless "acute" form and a fatal "chronic" one. Also like histoplasmosis, it sometimes produces lung lesions resembling those of tuberculosis.

The discovery by Drs. Christie and Palmer, and by others who made the same finding independently, that fungus infections may cause lung calcifications has brought to light and helped to clear up a number of studies that had puzzled medical investigators. The tuberculin skin test for tuberculosis is believed to be almost infallible. Yet for a number of years physicians making mass X-ray examinations of children have reported that many children with apparently tuberculous lung lesions reacted negatively to the tuberculin test. In one mass examination in the South in 1938, an investigator found that there were almost as many chest lesions among patients who reacted negatively to the tuberculin test as among those who reacted positively. More than 48 per cent of the negative reactors had these lesions. In a considerable number of cases, even tuberculosis specialists pronounced these patients tuberculous beyond any doubt. For lack of any other explanation, all lung calcifications had long been classified almost automatically as evidence of tuberculosis.

But in 1938 Dr. Palmer, after examining 7,000 school children in Hagerstown, Md., decided that a large proportion had lung calcifications which could not be explained as tuberculous. Soon afterward, a group of investigators who examined Indian children in the Southwest established by means of a skin test that many of their lung lesions were caused by coccidioidomycosis. In Xenia, Ohio, however, an examination of 500 orphanage children showed that lung lesions found among them could not be attributed either to tuberculosis or to coccidioidomycosis. The examiners suspected that the cause must be some other fungus. Dr. Christie's 1944 histoplasmin skin test in Nashville finally identified what seems to be the major cul-

prit: the fungus Histoplasma capsulatum.

Little is known about this ominous fungus. It appears in nature in two varieties, one harmless, the other parasitic and responsible for causing histoplasmosis in man. The parasitic type is believed to be insect-borne. But the method by which the disease is spread is unknown; present medical opinion is that it is probably a droplet infection that attacks man through the respiratory system. The first significant symptoms of the acute infection are usually found in the respiratory organs. The fungus shows an affinity for cells of the reticulo-endothelial system (*i.e.*, chiefly the spleen and liver). The histoplasmin skin test to detect the fungus employs an antigen made from a culture of Histoplasma capsulatum. Dr. Chester Emmons of the National Institute of Health has questioned whether the test is specific for histoplasmosis alone; in animal tests he has found that coccidioidomycosis and another fungus disease give positive reactions to the same test. Presumably standardization of the test will eliminate these cross-reactions.

The disease seems to be more prevalent among adults than among children. A study in Kansas City, Mo., showed that the highest incidence of positive reactions to the test (88 per cent) occurred in the group of men aged 35 to 40; among women the highest incidence (67 per cent) was in the age group from 20 to 24. The principal histoplasmosis centers are Missouri, Kansas, Ohio, Indiana, Illinois, Tennessee, Arkansas and Louisiana.

THE role of fungi in human pathology has been too long overlooked. Our interest in the mysterious biological relationship between fungus and man has been greatly stimulated in the last few years by the discovery and use of penicillin, a fungus which is employed in therapy. But even penicillin may invade tissues and produce severe complications, as we are now coming to realize.

The new and dramatic history of histoplasmosis may have something to contribute to the basic medical problem of the threshold between health and disease. We have supposed that, thanks to new synthetic and antibiotic drugs, we are becoming more and more independent of our bacterial invaders and symbiotic parasites. Now suddenly a new threat springs out of the biological underworld, perhaps even stimulated in this case by our recent use of fungus species such as penicillin and streptomycin for curing man's ancient diseases. Nevertheless, one may venture to look on the bright side of the matter and hope that the study of histoplasmosis will open an entirely new field of attack and defense in the battle for health.

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CULTURE of the histoplasmosis organism is a white, fluffy growth rather similar to that of many other fungi, making identification difficult. Sometimes diagnosis is assisted by culturing specimens of blood and other infected material from a patient suspected of having contracted disease.

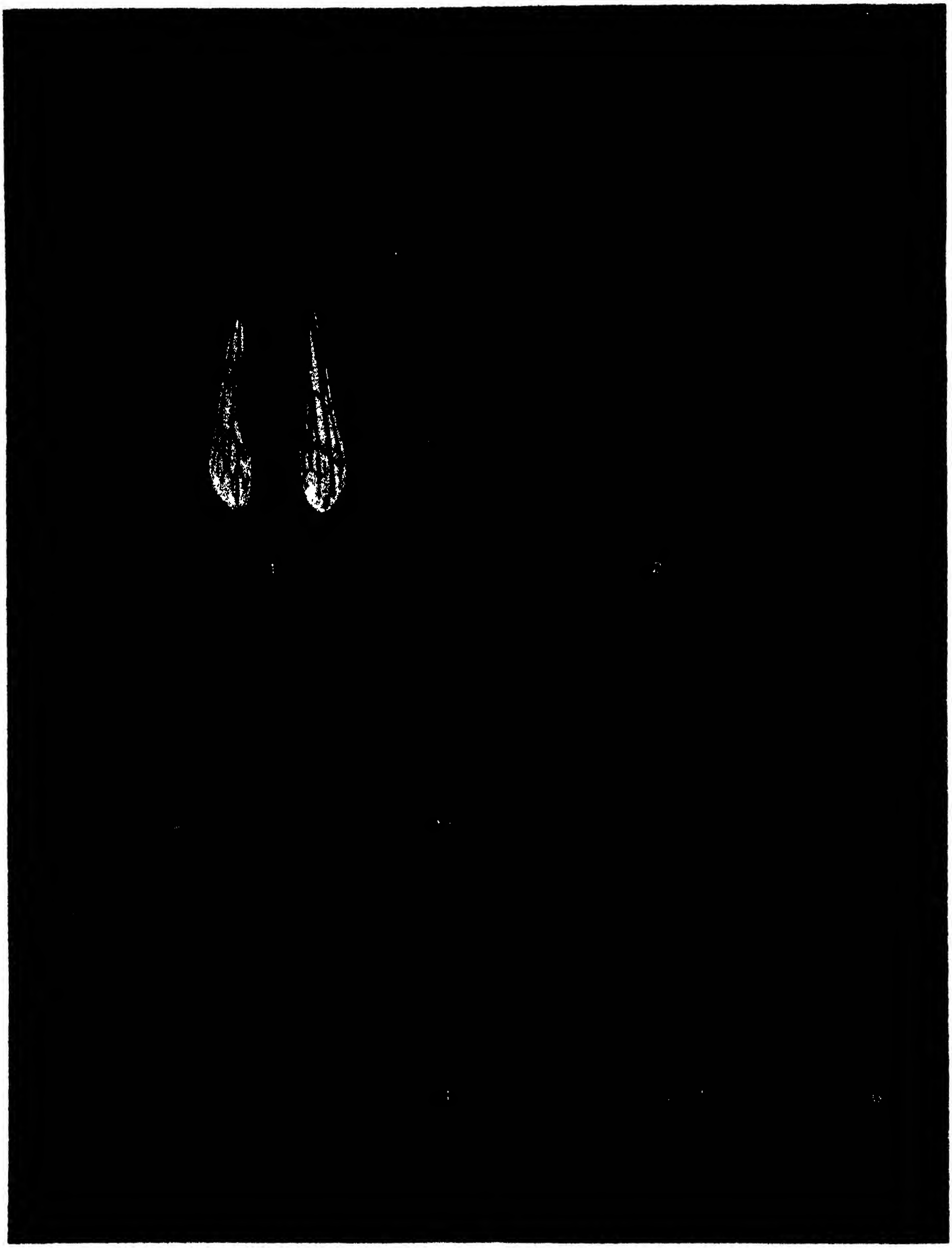


TABLE OF ORGANIZATION of an army ant colony is fixed by specialization in structure and function of its individual members, here shown 2.5 times life-size. Winged male (its appearance suggests the evolutionary link of ants to wasps) lives only long enough to mate a queen. Organization and behavior of the colony are polarized around queen (2) and her reproductive function. Workers, graded in size from major (3) down to minim (6) tend to specialize according to their size in defense, food-gathering or in nursing of offspring.

THE ARMY ANT

This explanation of how the creature conducts its complicated social life clearly distinguishes ants from men

by T. C. Schneirla and Gerard Piel

Wherever they pass, all the rest of the animal world is thrown into a state of alarm. They stream along the ground and climb to the summit of all the lower trees searching every leaf to its apex. Where booty is plentiful, they concentrate all their forces upon it, the dense phalanx of shining and quickly moving bodies, as it spreads over the surface, looking like a flood of dark-red liquid. All soft-bodied and inactive insects fall an easy prey to them, and they tear their victims in pieces for facility in carriage. Then, gathering together again in marching order, onward they move, the margins of the phalanx spread out at times like a cloud of skirmishers from the flanks of an army.

THAT is how Henry Walter Bates, a Victorian naturalist, described the characteristic field maneuvers of a tribe of army ants. His language is charged with martial metaphor, but it presents with restraint a spectacle which other eyewitnesses have compared to the predatory expeditions of Genghis Khan and Attila the Hun.

Army ants abound in the tropical rain forests of Hispanic America, Africa and Asia. They are classified taxonomically into more than 200 species and distinguished as a group chiefly by their peculiar mode of operation. Organized in colonies 100,000 to 150,000 strong, they live off their environment by systematic plunder and pillage. They are true nomads, having no fixed abode. Their nest is a seething cylindrical cluster of themselves, ant hooked to ant, with queen and brood sequestered in a labyrinth of corridors and chambers within the ant mass. From these bivouacs they stream forth at dawn in tightly organized columns and swarms to raid the surrounding terrain. Their columns often advance as much as 35 meters an hour and may finally reach out 300 meters or more in an unbroken stream. For days at a time, they may keep their bivouacs fixed in a hollow tree or some other equally protected shelter. Then, for a restless period, they move on with every dusk. They swarm forth in a solemn, plodding procession, each ant holding to its place in line, its forward-directed antennae beating a hypnotic rhythm. At the rear come throngs of larvae-carriers and, at the very last, the big, wingless queen, buried under a melee of frenzied workers. Late at night they hang their new bivouac under a low-hanging branch or vine.

The army ant, observers are agreed, presents the most complex instance of organized mass behavior occurring regularly outside the homesite in any insect or, for that matter, in any subhuman animal. As such, it offers the student of animal psychology a subject rich in interest for itself. But it also provides an opportunity for original attack on some basic problems of psychology in general. The study here reported, covering the behavior of two of the Eciton species of army ants, was conducted by Schneirla over a 16-year period with extended field trips to the Biological Reservation on Barro Colorado Island in the Panama Canal Zone and to other ant haunts in Central America. In undertaking it, he had certain questions in mind. The central question, of course, was how such an essentially primitive creature as the ant manages such a highly organized and complex social existence. This bears on the more general consideration of organized group behavior as an adaptive device in natural selection. There was, finally, the neglected question of the nature of social organization. This is primarily a psychological problem because it concerns the contribution of individual behavior and relationships between individuals to the pattern of the group as a whole. It was expected that reliable data on these questions in the instance of the army ant might throw light on similar questions about human societies.

WORKER MAJOR is equipped with a wasplike sting in its tail as well as with big mandibles. Its aggressive response to extra-colony stimuli makes it the "soldier" of army ants.

The ant commends itself to study by man. Measured by the dispassionate standard of survival, it stands as one of the most successful of nature's inventions. It is the most numerous of all land animals both in number of individuals and number of species (more than 3,500 at present count). It has occupied the whole surface of the globe between the margins of eternal frost. Its teeming cities are to be found even on isolated atolls in mid-Pacific. The oldest of living orders, the ant dates back 60 million years to the early Jurassic period. More significant, the societies of ants probably evolved to their present state of perfection no less than 50 million years ago. Man, by contrast, is a dubious experiment in evolution that has barely got under way.

IN the esteem of political philosophers, from Solomon to Winston Churchill, ants have shared honors with the two other classes of social insects, the bee and the termite. Of the three, the ant is by far the most various and interesting. Bees live in hives; termites burrow almost exclusively in wood. Ants are not so easily pigeonholed. Lord Avebury, a British formicologist, marveled at "the habits of ants, their large communities and elaborate habitations, their roadways, possession of

domestic animals and, even, in some cases, of slaves!" He might have added that ants also cultivate agricultural crops and carry parasols. It is the social institutions of ants, however, that engender the greatest enthusiasm. The late Henry Christopher McCook, in his *Ant Communities and How They are Governed, A Study in Natural Civics*, credited the ant with achieving the ultimate in democratic social order. The sight of an army ant bivouac put the British naturalist Thomas Belt in mind of Sir Thomas More's *Utopia*. The Swiss naturalist Auguste Forel urged the League of Nations to adopt the ant polity as the model for the world community.

The marvels of ant life have led some thinkers into giddy speculation on the nature of ant intelligence. Few have put themselves so quaintly on record as Lord Avebury, who declared: "The mental powers of ants differ from those of men not so much in kind as in degree." He ranked them ahead of the anthropoid apes. Maurice Maeterlinck, author of *The Life of the Ant*, hedged: "After all, we have not been present at the deliberations of the workers and we know hardly anything of what happens in the depths of the formicary." Others have categorically explained ant behavior as if the creatures could reason, exchange information, take purposeful action and feel tender emotion. Describing a tribe of army ants on the march in his book *Insect Behavior*, the American naturalist Paul Griswold Howes has "lieutenants keeping order or searching out the ground to be hunted or traveled next" and the privates in the line "obeying commands" and evincing "a wonderful sense of duty." Belt noted, as a matter of course, that "light-colored officers" keep the "common dark-colored workers" in line. R. C. Wroughton concluded from the precision of ant armies' maneuvers that "they are either the result of preconceived arrangement or are carried out by word of command."

Obviously anthropomorphism can explain little about ants, and it has largely disappeared from the current serious literature about ant behavior. Its place has been taken, however, by errors of a more sophisticated sort. One such is the concept of the "superorganism." This derives from a notion entertained by Plato and Aquinas that a social organization exhibits the attributes of a superior type of individual. Extended by certain modern biologists, the concept assumes that the biological organism, a society of cells, is the model for social organizations, whether ant or human. Plausible analogies are drawn between organisms and societies: division of function, internal communication, rhythmic periodicity of life processes and the common cycle of birth, growth, senescence and death. Pursuit of these analogies, according to the protagonists of the superorganism, will disclose that the same forces of natural selection have shaped the evolution of both organism and superorganism, and that the same fundamental laws govern their present existence.

This is of course a thoroughly attractive idea. It is representative, in the field of psychology, of current efforts in other fields of science to unify all observed facts by a single theory. But it possesses a weakness common to all Platonistic thinking. It erects a vague concept, "organism" or "organization," as an ultimate reality which defies explanation. The danger inherent in this arbitrary procedure is the bias which it imposes upon the investigator's approach to his problem. It reduces the gathering of evidence to the selection of appropriate illustrations and examples. This is a pitfall of which the investigator must be especially wary in the study of social behavior. Too often in this field theories and conclusions are composed of nine parts of rationalization to one part of evidence. The investigator in social science must be ruthless in discarding his preconceived notions, taking care to retain only the bare conceptual framework that is inductively supported by the already established evidence on his subject. In the gathering of new evidence he must impose on his work the same rules of repetition and control which prevail in the experimental sciences. Wherever possible he should subject his observations to experimental tests in the field and laboratory. In the area we are discussing this kind of work may at times seem more like a study of ants than an investigation of problems. But it yields more dependable data.

ONE of the most helpful sources of evidence concerning the ant is the study of the ant in its "more than royal tomb" of amber. This is the paleontologist's ant, trapped eons ago in the sticky gum of a conifer and thereby preserved intact for examination by scientists today. They find that the fossil ant is in all major respects identical with its twentieth-century descendants. From this evidence biologists reason that since the social behavior of the ant is primarily a function of its biological make-up, ant societies must be as ancient as the ant. This conclusion is supported by studies of ant behavior. The contemporary ant, as will be shown, exhibits a comparatively limited capacity for learning. On the other hand, there is little that it needs to learn when it crawls out of the cocoon. By far the greater part of its behavior pattern is already written in its genes and represents the "learning" of its race, acquired many generations ago in the hard school of natural selection.

The individual ant, as a matter of fact, is ill-equipped for advanced learning. By comparison with the sensitive perceptions of a human being, it is deaf and blind. Its hearing consists primarily in the perception of vibrations physically transmitted to it through the ground. In most species, its vision is limited to the discrimination of light and shadow. These deficiencies are partially compensated by the chemotactual perceptions of the ant, centered in its flitting antennae. Chiefly by means of its antennae, the ant tells friend from foe, locates its booty, and, thanks to its habit of signing its trail with droplets from its anal gland, finds its way home to the nest.

In an investigation of ant learning, Schneirla found that individual ants are capable of significant feats of progress in a given situation, but that on the whole ant learning is by rote. His subject in this study was the common garden Formica ant, which is known to forage freely within a radius up to 75 meters around its nest. The learning situation was presented by a maze, interposed between the laboratory nest and feeding box, with maze passages open on the return route to the nest. Each individual ant was identified and followed by means of a number pasted on its gaster (abdomen). The ants betrayed no evidence of purposive behavior. Compared to the rat, which in the same maze pattern may acquire a pronounced "goal set" and make straight for the other end of the maze after relatively few runs, the ants were at first quite haphazard in their behavior. It required almost a dozen runs before they ceased crawling aimlessly on the floors and walls of the first alley in the maze. Their learning curves then ascended steeply to a flat plateau; thereafter, they made as many wrong turns at the last choice points in the maze as they did at the first.

Control of clues provided in the maze by ant chemicals and variations in lighting revealed that the Formica ant possesses considerable learning capacity in its kinesthetic or "muscle" sense. Nevertheless, this study shows that the ant acquires merely a generalized maze habit, not an understanding of mazes. This conclusion is reinforced by another comparison with the rat. Confronted with abrupt changes in the maze layout, the rat will often exhibit plain evidence of emotional conflict, represented by an over-all deterioration of its learning progress. Ants, in the same situation, merely blunder ahead.

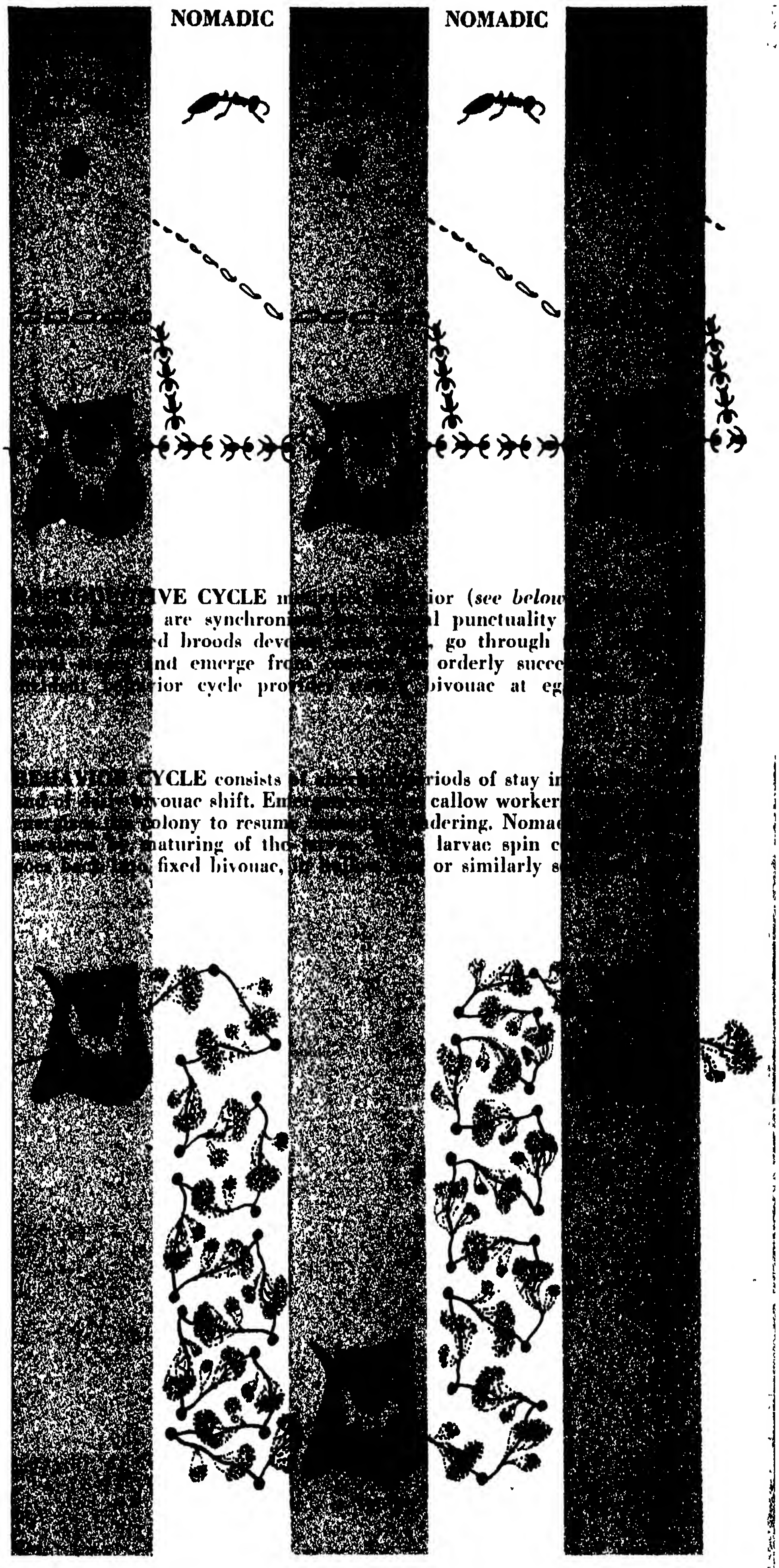
How the essentially uncomplicated repertory of the individual ant contrives, when ants act in concert, to yield the exceedingly complex behavior of the tribe is one of the most intricate paradoxes in nature. This riddle has been fruitfully explored during the past generation under the guidance of the concept of "trophallaxis," originated by the late William Morton Wheeler of Harvard University, who ranks as the greatest of U.S. formicologists. Trophallaxis (from the Greek *trophe*, meaning food, and *allaxis*, exchange) is based upon the familiar observation that ants live in biological thrall to their nestmates. Their

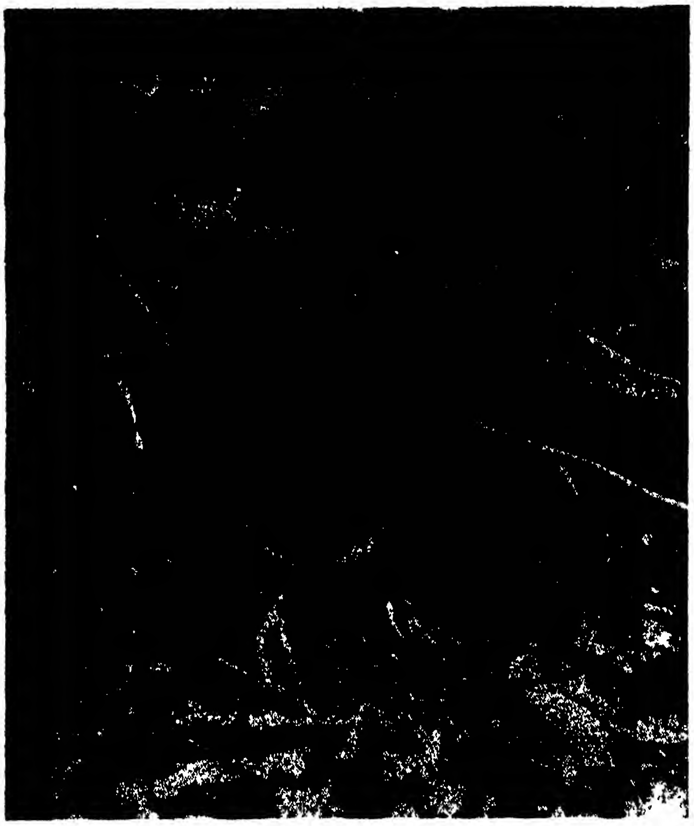
powerful mutual attraction can be seen in the constant turning of one ant toward another, the endless antennal caresses, the licking and nuzzling. In these exchanges they can be seen trading intimate substances—regurgitated food and glandular secretions. Most ants are dependent for their lives upon this biosocial intercourse with their fellows. There is strong evidence that, as between larvae, workers and queen in a given tribe, there is an interchange of co-enzymes necessary to the existence of all. Army ant queens unfailingly sicken and die after a few days when isolated in captivity.

Trophallaxis, or "the spirit of the formicary," as Maeterlinck was pleased to call it, is therefore essentially chemical in nature. As can be seen by the mutual attractions and repulsions of ants for one another, their social chemicals are not only specific to species but also specific to colonies. Schneirla's most acute memory of his 16-year association with army ants is the characteristic Eciton odor which emanates from their columns, an odor reminiscent of potato blossoms. It is obscured near their bivouacs by the fetid smells which emanate from the decaying fragments of booty clinging to individual ants. The army ant queen, less exposed to offal, is distinguished by a delicate, indefinable odor. All this suggests that biochemists may here find a field for studies which should yield more effective ant repellents and poisons, as well as shed new light on animal behavior.

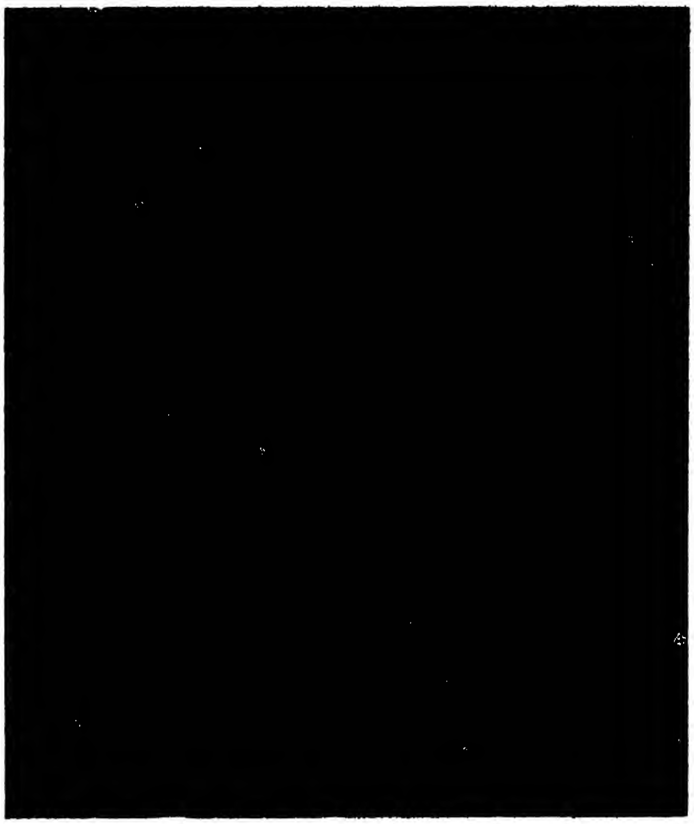
THE well-established concept of trophallaxis naturally suggests that clues to the complex behavior of the ant armies should be sought in the relationships among individuals within the tribe. Most investigators have looked elsewhere, with invariably mistaken results. In attempting to explain, for example, why an ant army alternates between periods of fixed bivouac and nomadic wandering, a half-dozen reputable scientists have jumped to the simplest and most disarmingly logical conclusion: food supply. The ants, they declared, stay in one place until they exhaust the local larder and then move on to new hunting grounds. Schneirla has shown, however, that the true explanation is quite different.

The migratory habits of the ant armies follow a rhythmically punctual cycle. The *Eciton Hamatum* species, for example, wanders nomadically for a period of 17 days, then spends 19 or 20 days in fixed bivouac. This cycle coincides precisely with the reproductive cycle of the tribe. The army goes into bivouac when the larvae, hatched from the last clutch of eggs, have gone into the pupal state in their cocoons. At the end of the first week, the queen, with her gaster swollen to more than five times its normal volume, goes into a stupendous five- to seven-day labor in which she delivers 20,000 to 30,000 eggs. The daily foraging raids, which





BIVOUAC is a more or less cylindrical hollow cluster of the members of a colony. It builds from above downward as strings and filaments of ants, hooked together leg to leg, descend from log or vine. This is a typical nomadic period bivouac, hanging exposed in the open.



CLOSE-UP of bivouac suggests "fur of some terrible animal." Outer "tissue" of structure, as shown here, is made of workers major and intermediates. Minims concentrate around queen within. When pouchlike bivouac is poked with stick, larvae and cocoons pour out.

meanwhile have dwindled to a minimum, pick up again as the eggs hatch into a great mass of larvae. Then, on about the 20th day, the cocoons yield a new generation of callow workers, and the army sets off once more on its evening marches.

In determining this pattern of external social events Schneirla logged a dozen ant armies through one or more complete cycles, and upwards of 100 through partial cycles. Observations were set down in shorthand in the field. The coinciding pattern of internal biological events was documented by brood samples taken from many different colonies at various stages in the reproductive cycle. In the course of the last field trip, from November 1947 to March 1948, broods of more than 80 colonies were sampled, most of them repeatedly at intervals of a few days. In addition, detailed examinations were made of 62 queens in various phases of their physiological history and many of these were preserved for further study.

A SENTIMENTALIST considering this new picture of the army ant's domestic habits may find an explanation for its behavior more affecting than the food theory: the ants stay in fixed bivouac to protect the queen and her helpless young through the time when they are most vulnerable. Doubtless this is the adaptive significance of the process. But the motivation which carries 100,000 to 150,000 individual ants through this precisely timed cycle of group behavior is not familial love and duty but the trophallactic relationship among the members of the tribe. A cocooned and slumberous pupa, for example, exerts a quieting influence upon the worker that clutches it in its mandible—somewhat as a thumb in the mouth pacifies an infant. But as it approaches maturity and quickens within its cocoon, the pupa produces precisely the reverse effect. Its stirring and twitching excite the workers to pick up the cocoon and snatch it from one another. As an incidental result, this manhandling effects the delivery of the cocoon's occupant. (Cocoons in which the pupae were killed by needle excited no such interest among the workers and remained unopened.)

The stimulus of the emerging brood is evident in a rising crescendo of excitement that seizes the whole community. Raiding operations increase in tempo as the hyperactive, newly delivered workers swarm out into the marching columns. After a day or two, the colony stages an exceptionally vigorous raid which ends in a night march. The bivouac site is left littered with empty cocoons. Later in the nomadic period, as the stimulus of the callow workers wanes, the larvae of the next generation become the source of colony "drive." Fat and squirming, as big as an average worker, they establish an active trophallactic relationship with the rest of the tribe. Workers constantly stroke them with their antennae, lick them with their mouth parts and carry them bodily from place to place. Since the larvae at this stage are usually well distributed throughout the corridors and the chambers of the overnight bivouac, their stimulus reaches directly a large number of the workers. This is reflected in the sustained vigor of the daily raids, which continue until the larvae spin their cocoons.

THESE observations are supported by a variety of experimental findings in the field and laboratory. The role of the callow workers in initiating the movement to break bivouac was confirmed by depriving a number of colonies of their callow broods. Invariably, the raiding operations of the colony failed to recover from the lethargic state characteristic of the statary periods. Some tribes even extended their stay in fixed bivouac until the larvae grew large and active enough to excite the necessary pitch of activity. To test the role of the larval brood, captured tribes were divided into part-colonies of comparable size. The group with larvae showed much greater activity than those that had no larvae or that had cocoons in the early pupal state.

The interrelationships among members of the colony thus provide a complete explanation for the behavior cycle of the

QUEEN in labor has already delivered several thousand eggs, still has upwards of 20,000 to go. Exoskeletal plates of her enormously swollen gaster are widely separated, exposing the distended membrane. Workers attend labor excitedly, snatch up eggs when they emerge.

COLUMN of army ants on a bivouac-shift march is an inch wide, may stretch upwards of 300 meters in length. In this picture, the queen appears just above center, buried under excited workers. Attraction of queen is indicated also by a reversal in travel of workers ahead.

army ant. It should be observed, in conclusion, that the whole complex process is carried out by individuals which do not themselves originate the basic motivations of their behavior.

Long before the intricacies of its domestic existence were suspected, the army ant's reputation as a social animal was firmly established by its martial conduct in external affairs. It does not require an overactive imagination to perceive the classic doctrines of offensive warfare spelled out by the action of an ant army in the field. It carries through the maneuvers of wheeling, flanking and envelopment with a ruthless precision. But to find its motivations and explain its mechanics, one must consult the ant, not von Clausewitz.

Army ant raids fall into one of two major patterns. They are organized either in dense swarms which form at the head of the column or in a delicate tracery of capillary columns branching out at the forward end of the main raiding column. Both types of raiding are found in subgenera of each of the common species of Central American army ant. The *Eciton eciton* species was selected for this study because it leads its life entirely on the surface of the jungle floor and is thus accessible to continuous observation. Whether the army ants raid in swarm or column, however, the essential mechanics of their behavior are substantially the same.

The bivouac awakes in the early dawn. The stir of activity begins when the light (as measured by photometer) reaches .05 foot candles, and it mounts steadily as the light increases. In strands and clusters, the workers tumble out of the bivouac into a churning throng on the ground. A crowding pressure builds up within this throng until, channeled by the path of least resistance, a raiding column suddenly bursts forth. The ants in the column are oriented rigidly along the line of travel blazed by the chemical trail of the leaders. The minims and medium-sized workers move in tight files in the center. The "workers major," displaced by the unstable footing afforded by the backs of their smaller fellows, travel along each side. This arrangement no doubt lends suggestive support to the major's legendary role of command. It has an adaptive significance in that it places the biggest and most formidable of the workers on the flanks. Unless disturbed, however, the majors hug the column as slavishly as the rest. The critical role of the tribal chemical in creating this drill sergeant's picture of order may be demonstrated by a simple field experiment. Removal of the chemically saturated litter from the trail brings the column to an abrupt halt. A traffic jam of ants piles up on the bivouac side of the break and is not relieved until enough ants have been pushed forward to re-establish the chemical trail.

Appearances are less ordered at the front of the column, where the "scouts" and "skirmishers" are most frequently observed. The timid individual behavior of the forward ants scarcely justifies such titles. Compared with the Formica, the Eciton is a far less enterprising forager. It never ventures more than a few inches into the chemically-free area ahead. Even this modest venturing is stimulated principally by physical impact from the rear. At the end of its brief pioneering sally, the Eciton rebounds quickly into the column. It is here that the critical difference between column and swarm raiding arises. The column-raiding ants are somewhat freer in their pioneering behavior and so open new pathways more readily. In the swarm raiders the comparatively reluctant progress of the forward elements creates a counterpressure against the progress of the column. This forces the head of the column into a broad elliptical swarm which arrays itself at right angles to the line of march. With ants pouring in from behind, the swarm grows steadily in size as it moves forward, often achieving a width of more than 15 meters.

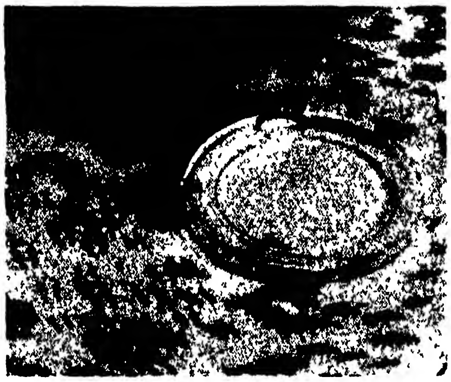
THE PATH of an ant army, whether in swarms or columns, shows no evidence of leadership. On the contrary, each individual makes substantially the same contribution to the group behavior pattern. The army's course is directed by such

wholly chance factors as the stimulus of booty and the character of the terrain. On close inspection, therefore, it appears that the field operations of ant armies approximate the principles of hydraulics even more closely than those of military tactics. This impression is confirmed by analysis of the flanking maneuver as executed by the swarm raiders. A shimmering pattern of whirls, eddies and momentarily milling vortices of ants, the swarm advances with a peculiar rocking motion. First one and then the other end of the elliptical swarm surges forward. This action results in the outflanking of quarry, which is swiftly engulfed in the overriding horde of ants. It arises primarily, however, from an interplay of forces within the swarm. One of these forces is generated by the inrush of ants from the rear. Opposed by the hesitant progress of the swarm, the new arrivals are deflected laterally to the wing which offers least resistance. This wing moves forward in a wheeling motion until pressure from the slow advance of its frontal margins counterbalances the pressure from the rear. Pressure on the opposite wing has meanwhile been relieved by drainage of the ants into the flanking action. The cycle is therewith reversed, and a new flanking action gets under way from the other end. External factors, too, play a role in this cycle. The stimulus of booty will accelerate the advance of a flank. The capture of booty will halt it and bring ants stampeding in for a large-scale mopping-up party. But raiding activity as such is only incidental to the process. Its essential character is determined by the stereotyped behavior of the individual ant with its limited repertory of responses to external stimuli.

THE profoundly simple nature of the beast is betrayed by an ironic catastrophe which occasionally overtakes a troop of army ants. It can happen only under certain very special conditions. But, when these are present, army ants are literally fated to organize themselves in a circular column and march themselves to death. Post-mortem evidence of this phenomenon has been found in nature; it may be arranged at will in the laboratory. Schneirla has had the good fortune to observe one such spectacle in nature almost from its inception to the bitter end.

The ants, numbering about 1,000, were discovered at 7:30 a.m. on a broad concrete sidewalk on the grounds of the Barro Colorado laboratories. They had apparently been caught by a cloudburst which washed away all traces of their colony trail. When first observed, most of the ants were gathered in a central cluster, with only a company or two plodding, counterclockwise, in a circle around the periphery. By noon all of the ants had joined the mill, which had now attained the diameter of a phonograph record and was rotating somewhat eccentrically at fair speed. At 10:00 p.m. the mill was found divided into two smaller counter-clockwise spinning discs. At dawn the next day the scene of action was strewn with dead and dying Ecitons. A scant three dozen survivors were still trekking in a ragged circle. By 7:30, 24 hours after the mill was first observed, the various small myremicine and dolichoderine ants of the neighborhood were busy carting away the corpses.

This peculiarly Eciton calamity may be described as tragic in the classic meaning of the Greek drama. It arises, like Nemesis, out of the very aspects of the ant's nature which most plainly characterize its otherwise successful behavior. The general mechanics of the mill are fairly obvious. The circular track represents the vector of the individual ant's centrifugal



IN LABORATORY, circular-column milling by army ants is spontaneous and common event. Mill may be started by a few ants circling a dish or short-cutting square corners of nest.

impulse to resume the march and the centripetal force of trophallaxis which binds it to its group. Where no obstructions disturb the geometry of these forces, as in the artificial environment of the laboratory nest or of a sidewalk, the organization of a suicide mill is almost inevitable. Fortunately for the army ant, it is rare in the heterogeneous environment of nature. In the diversity of its natural habitat, the stereotyped army ant is presented with innumerable possibilities for variation in its activity. The jungle terrain, with its random layout of roots and vines, leaves and stones, liberates the ant from its propensity to destroy itself and diverts it into highly adaptive patterns of behavior.

The army ant suicide mill provides an excellent occasion for considering the comparative nature of social behavior and organization at the various levels from ants to men. Other animals occasionally give themselves over to analogous types of mass action. Circular mills are common among schools of herring. Stampeding cattle, sheep jumping fences blindly in column and other instances of pell-mell surging by a horde of animals are familiar phenomena. Experience tells us that men, too, can act as a mob. These analogies are the stock-in-trade of the "herd instinct" schools of sociology and politics. They are cited by those who hold that emotionalized, individually degraded, regimented patterns are the rule in group behavior of mankind.

We are required, however, to look beyond the analogy and study the relationship of the pattern to other factors of individual and group behavior in the same species. In the case of the army ant, of course, the circular column really typifies the animal. Among mammals, such simplified mass behavior occupies a clearly subordinate role. Their group activity patterns are chiefly characterized by great plasticity and capacity to adjust to new situations. This observation applies with special force to the social potentialities of man. When human societies begin to march in circular columns, the cause is to be found in the strait-jacket influence of the man-made social institutions which foster such behavior. The phenomenon of milling, it turns out, has entirely different causes and functions at different levels of social organization. The differences, furthermore, so far outweigh the similarities that they strip the "herd instinct" of meaning.

The same reservations apply to the analogies cited to support the superorganism theory. Consider, for example, the analogy of "communication." Among ants it is limited to the stimulus of physical contact. One excited ant can stir a swarm into equal excitement. But this behavior resembles the action of a row of dominoes more than it does the communication of information from man to man. The difference in the two kinds of "communication" requires two entirely different conceptual schemes and preferably two different words.

As for "specialization of functions," that is determined in insect societies by specialization in the biological make-up of individuals. Mankind, in contrast, is biologically uniform and homogeneous. Class and caste distinctions among men are drawn on a psychological basis. They break down constantly before the energies and talents of particular individuals.

Finally, the concept of "organization" itself, as it is used by the superorganism theorists, obscures a critical distinction between the societies of ants and men. The social organizations of insects are fixed and transmitted by heredity. But members of each generation of men may, by exercise of the cerebral cortex, increase, change and even displace given aspects of their social heritage. This is a distinction which has high ethical value for men when they are moved to examine the conditions of their existence.

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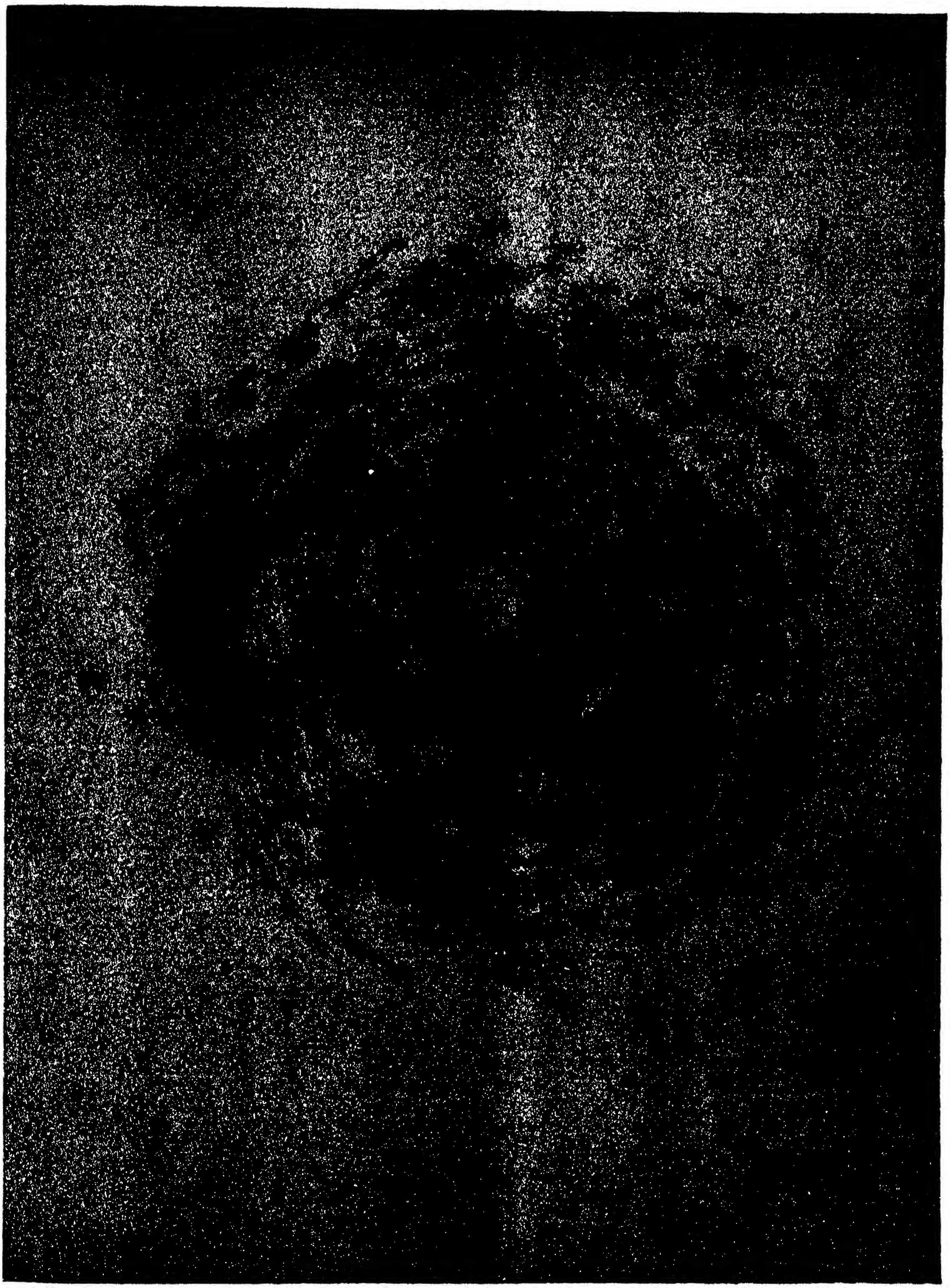
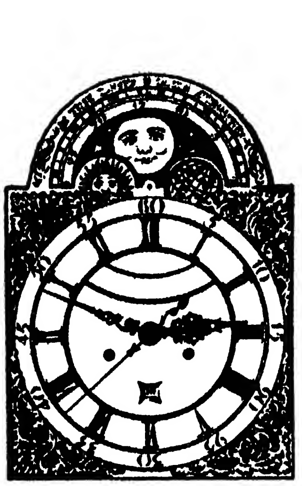


CIRCULAR COLUMN described in text on opposite page is shown here in drawing traced from photograph. Tendency to form such columns betrays essential mechanics of army ant behavior. This mill developed from cluster of ants that had been isolated accidentally on a sidewalk. Stereotyped ants slavishly followed chemical trail laid by first few individuals that ventured out of cluster. As heat of day speeded travel of ants, the resulting centrifugal force increased the size of the mill to an outside diameter of about seven inches.

SCIENCE AND THE



Atomic Energy Abroad

A FEW weeks ago Dr. L. Kowarski, the distinguished nuclear physicist who is scientific director of the French Atomic Energy Commission, paid a flying visit to the U.S. At Brookhaven National Laboratory he gave a talk on the progress of atomic energy research in western Europe. The gist of his report:

Both in terms of manpower and funds, Britain's atomic energy effort is about one tenth the American, and the French is one tenth the British. Next in magnitude is the Swedish program.

As is well known, an experimental low-energy pile is already in operation at Harwell, the main British atomic energy research station. This establishment is about the size of Brookhaven or the Argonne National Laboratory in Chicago. In France, a low-energy pile will be completed late this year or early in 1949. The Swedish pile project is not scheduled to be finished until some time later.

In Kowarski's opinion, no other country in western Europe has the resources to develop a pile of its own. In fact, he thinks that Sweden may find it impossible to carry her project through to completion. Norway also has a pile project, based on her large heavy water plants, but Kowarski is pessimistic concerning its outcome. Nor can Switzerland, despite her high-quality technical resources, develop a pile. In the Netherlands, several major nuclear research projects are under way, but construction of a pile is not contemplated.

Social Research

DURING the late war British scientists became enthusiastic champions of "operational research"—a system of applied team study by men in different sciences which was brilliantly successful in solving many specific military problems, especially in aerial and submarine warfare. Now a group of outstanding British men of science from various fields have joined in proposing a plan to apply operational research to Britain's pressing economic problems.

The proposal is to establish a Social Sciences Research Council, to operate in the social sciences in Great Britain in somewhat the same fashion as the National Science Foundation is intended to operate in the natural sciences in the U.S. The report which outlines the plan, drafted by a committee of the British Association of Scientific Workers, has become a best seller in England. Its chief thesis is that Britain's recovery must be guided by greater use of the social sciences.

It points out that Great Britain, recognizing that her economic future depends on better and more efficient production, has already raised her expenditures for technological research. In a very few fields, these have been matched by increased expenditures for related social research; in the field of housing, for example, scientific teams are studying not only how to build better houses, but what kind of houses ought to be built. This approach, it is argued, should be done on a larger scale and in many more fields. So far, the report declares, Britain has made little use—less than the U.S.—even of such comparatively simple social science techniques as vocational aptitude testing.

The report proposes that the Social Sciences Research Council should sponsor and conduct research, survey the work being done in various fields, and organize operational research teams to tackle outstanding public problems. It also urges establishment of social research units in government departments and the expansion of university social science faculties.

Code for Scientists

A UNIQUE "Charter for Scientists" has been drawn up by the World Federation of Scientific Workers, an organization initiated two years ago by the powerful British Association of Scientific Workers. The Charter is eventually to be adopted by the Federation's 19 affiliates in 15 countries as a part of their bylaws. It provides a kind of Hippocratic oath for scientists. Its preamble points out that the profession of science, being of comparatively recent origin, lacks a code such as governs older professions like medicine and the law. The Charter seeks to fill this gap.

The Charter states explicitly that the scientist is obligated to "maintain the international character of science, to aid agencies seeking to prevent war and to resist the diversion of scientific effort to war aims." It lays down conditions of work for scientists, from adequate salaries and facilities to the free right of publication and the abolition of secrecy. It further demands that scientists be permitted to participate in the management of agencies, whether government or private, that conduct research. It criticizes sharply, as destructive of scientific progress, the widespread tendency to subordinate scientists to non-scientists in research organizations.

The Charter also urges a manifold extension of science education in all countries. Two things are asked: free education for student scientists, and the inclusion of science in all school curricula so as to make science, like music and art, an accepted part of every individual's cultural background.

BCG

WITH $2 million from the International Children's Emergency Fund, the largest BCG vaccination program ever undertaken is under way in 11 European countries. Its object is to save European children from tuberculosis.

As a result of semistarvation, two thirds of the children in the 11 countries (Albania, Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Poland, Rumania and Yugoslavia) already have or have had tuberculosis. The other third can be saved only by an immediate increase in food rations or immunization measures. Since the former is out of the question, the latter is being taken up. About 15 million children altogether—all those susceptible to tuberculosis as determined by mass tuberculin testing—will be treated with BCG, a vaccine prepared from a weakened strain of tuberculosis bacteria. The campaign, which is under the direction of Dr. Johannes Holm, technical director of the Danish Red Cross, is a cooperative undertaking of the World Health Organization, the several Scandinavian Red Cross organizations and the 11 governments.

AEC Progress

THE Atomic Energy Commission has just reported several new developments in its program of medical and economic applications of atomic energy. One of them is the use of radioactive cobalt as a supplement to radium in the treatment of cancer. Radiocobalt tubes and needles are prepared by treatment in the atomic pile after fabrication from ordinary cobalt. They are inserted into tumors in much the same way as the usual gold "seeds" filled with the radioactive gas radon, and will accomplish no more and no less than the latter. They will not eliminate radon, for radiocobalt has a much longer radioactive half-life than radon and, though less expensive, involves greater hazards. Clinical trials of the new tubes and needles will soon be made.

About 200 agricultural studies are under way in which AEC-supplied radio-

CITIZEN

isotopes are employed as tracers. In a new project, for which the Commission is providing funds as well as material, isotopes are to be utilized not as tracers, but to determine the effects of radioactivity on plant growth. Almost since the discovery of radioactivity in 1896, a considerable body of European scientific opinion has contended that small doses of radiation stimulate the growth of crops. Actual experimental work both here and abroad has been inconclusive; results have sometimes been good and sometimes bad, and where good, may have been due to rare minerals present in the radioactive materials. Now the matter is to be put to the test, with the help of the AEC, by the Department of Agriculture and a number of cooperating state agricultural experiment stations.

In the area of basic research, the Commission announced the finding of evidence for the "exchange current" theory of nuclear binding forces (*see article beginning on next page*) by Drs. Herbert L. Anderson and Aaron Novick at the Argonne National Laboratory. Anderson and Novick measured the magnetic forces in hydrogen 3 and helium 3. Their data, they report, demonstrate that nuclei are held together by a flow of current within the nucleus as electric charges shift from one nuclear particle to another.

UNAEC Suspends

TWO YEARS of effort to frame an agreement on control of atomic energy through the United Nations have ended in failure, at least for the time being. On May 7, the American, British and French delegates to the UN Atomic Energy Commission proposed that the Commission suspend further discussion and report its inability to agree to the Security Council and General Assembly. The resolution's acceptance by the Commission seemed a foregone conclusion; the only members opposed were Russia and the Ukraine.

In support of their proposal, the American, British and French delegates prepared a report in which Russian intransigence and the general deterioration of relations between Russia and the West were blamed for the failure.

Meetings for July

FIRST International Poliomyelitis Conference. New York, July 12-17.

American Society of Civil Engineers. General meeting. Seattle, Wash., July 21-23.

International Union of Crystallography. Cambridge, Mass., July 28-August 3.

The Ultimate Particles

Presenting a comprehensive review of what is known thus far about the fundamental units of matter and the forces that play among them in the atom's core

by George W. Gray

And yet so poor is nature with all her craft, that, from the beginning to the end of the universe, she has but one stuff . . . to serve up all her dream-like variety. Compound it how she will—star, sand, fire, water, tree, man—it is still one stuff and betrays the same properties.

· Ralph Waldo Emerson,
Essay on Nature

SCIENCE today is concerned with a multitude of problems, many of them of a fundamental character, but none is more basic than the search for the ultimate units of matter and energy. Thales of Miletus posed the question 25 centuries ago when he asked: "Of what and how is the world made?" It is still the supreme enigma. The world includes man, and the elucidation of its nature cannot but reveal something of the hidden nature of life and of man.

Our question, therefore, is not alien to our humanity. The ultimate particles which enter into combination to make hydrogen and iron also enter into the construction of bone and muscle, blood and nerve and brain. In studying the constitution of atoms we are studying the fundamental stuff of the universe—of suns and mountains and seas, the black carbon of coal, the green chlorophyll of grass, the red hemoglobin of blood.

The forces which energize the elementary particles to cause nuclear cohesion, or under other conditions to cause nuclear fission, are not to be set apart as members of a remote, inhuman realm known as physics. These mighty forces are within us: they are ourselves, the very foundations of that matter and energy whose interplay constitutes all that we experience of the physical universe. Indeed, nature knows no such specializations as physics, chemistry, biology and the other categories into which we fit our fragments of knowledge. She knows only the particles and their incessant interactions as expressed in phenomena such as magnetism, radiation, life, death.

CLOUD CHAMBER reveals powerful beam of alpha particles fired by the 184-inch cyclotron at the University of California. Beam is curved by a magnetic field about the chamber.

I. Particles

A biologist probing the minute architecture of protoplasm must wield his dissecting needle with extreme delicacy, else he may destroy the thing he is trying to explore. But the physicist, wishing to unveil the still more minute architecture of the atom, resorts to artillery. His method is that of banging one particle against another, and the harder the blow, the more revealing is the debris resulting from the violence.

The value of the bombardment technique was shown a half century ago when Wilhelm Konrad Röntgen, experimenting at the University of Würzburg with cathode rays, discovered a mysterious radiation coming from that part of the glass tube against which the stream of cathode rays (electrons) impinged. The discovery of these X-rays in 1895, of radioactivity in 1896, of the electron in 1897 and of radium in 1898—those four golden years which ushered in the heroic age of physics!—brought not only revolutionary knowledge, but also new and powerful research tools.

A few weeks after Rontgen's discovery, J. J. Thomson used X-rays to bombard air and other gases and found that the rays knocked out negatively-charged fragments which eventually were identified as *electrons*. The discovery of radioactivity later led to the finding of alpha particles. It was by using the alpha particles which spontaneously shoot out of radium and other radioactive elements that Ernest Rutherford in 1911 bombarded gold into betrayal of its nucleus. Subsequent batterings showed that all atoms have this central, massive, positively-charged core around which the electrons revolve as negatively-charged satellites. Alpha particles themselves were found to be helium nuclei. In 1919 the alpha-particle barrage turned up another fundamental of structure when Rutherford bombarded nitrogen and found positively-charged *protons* bouncing out of the nitrogen nucleus. Thirteen years later the same artillery helped James Chadwick to blast out a still more elusive nuclear constituent, the *neutron*.

Britain was the scene of the Thomson, Rutherford, and Chadwick discoveries,

ACKNOWLEDGEMENT

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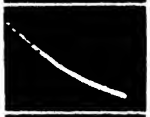
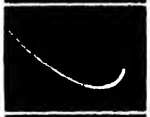
THE FUNDAMENTAL PARTICLES

(AS OF MAY 1948)

This chart lists the particles which are currently accepted by the majority of physicists. It lists only elementary particles: it does not include compound particles such as the deuteron and the alpha particle. Nor does it include the "nucleon." This is covered by neutron and proton, for which nucleon is the more general term.

MASS PARTICLES

PARTICLE	CHARGE	MASS	DISCOVERED	TRACK
ELECTRON	—	1	BY THOMSON, 1897	
PROTON	+	1836	BY RUTHERFORD, 1919	
NEUTRON	0	1836	BY CHADWICK, 1932	
POSITRON	+	1	BY ANDERSON AND NEDDERMEYER, 1932	
MESON MU	—	200	BY ANDERSON AND, INDEPENDENTLY, STREET AND STEVENSON, 1936	
MESON MU	+	200		
MESON PI	—	320	BY POWELL, OCCHIALINI AND LATTES, 1947	
MESON PI	+	320		
NEUTRAL MESON	0	88	SUGGESTED	

ENERGY PARTICLES

PHOTON	0	0	SUGGESTED BY EINSTEIN, ELABORATING ON PLANCK, 1905	
NEUTRINO	0	0 ?	SUGGESTED BY PAULI AND FERMI, 1931	

but it was America's turn next. Carl D. Anderson and Seth H. Neddermeyer at the California Institute of Technology were photographing the tracks which cosmic rays make darting through a Wilson cloud chamber, of which more later, when suddenly they espied a strange new track. It was similar in density and angle of curvature to paths previously made by electrons smashed out of atoms, but under the pull of magnetism it curved to the left whereas the paths of electrons curved to the right. This showed that the new particle had a positive charge. Thus, by the chance hit of a cosmic ray, the positively-charged electron was discovered. Anderson named it *positron*.

Nor was this all that the cosmic rays had in store. Four years later the same mysterious bombardment from outside the earth's atmosphere, accidentally smashing an atom in this same California laboratory, gave the track of another kind of particle. The density of its path, its angle and direction of curvature, indicated a negatively-charged mass which Anderson described as "larger than that of a normal free electron and much smaller than that of a proton." The same discovery was being made simultaneously by J. C. Street and E. C. Stevenson at Harvard. They determined the mass of the particle as about 130 times the weight of the electron. Later determinations have fixed the weight more closely as 200. Because of its "in-between" mass, Anderson named the particle *mesotron*, from the Greek meaning "intermediate." In usage the word has been shortened to *meson*, and both names are used interchangeably at present.

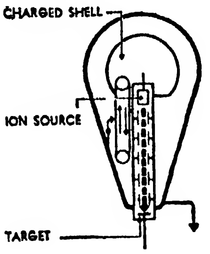
IN 1947 other particles of mass intermediate between those of electron and proton were discovered by C. F. Powell, G. P. S. Occhialini, and C. M. G. Lattes at the University of Bristol, in England. Studying a group of photographic plates which had been exposed to cosmic rays in the Bolivian Andes (cosmic rays are more abundant at high altitudes), they found the tracks of objects whose masses appeared to be about 320 times the electron mass. Some had positive charges, some negative. For convenience, heavyweights are called *pi* mesons. The previously discovered lightweights of 200 mass are called *mu* mesons. There is also evidence for a neutral meson of about 88 mass. Thus there are now known to be at least five kinds of mesons—positive and negative *pi*, positive and negative *mu*, and one neutral. Mesons of other masses, both lighter and heavier, have been inferred from a few cosmic-ray photographs, but the evidence is sketchy and they remain question marks.

In addition to the particles of matter just described, a bombarded atom may yield up radiant energy. And since these radiations behave as chunks when they strike our detectors, the energy units also

must be listed among the particles. They are called *photons*, and they come out of the atom in an almost infinite variety of sizes—as visible light, X-rays, gamma rays and other forms of electromagnetic radiation.

Besides photons, another kind of energy particle is believed to exist. The first hint of it came from beta particles, which are electrons that certain radioactive nuclei discharge spontaneously. In the case of radium E, for example, the nucleus ejects an electron and becomes polonium, and later the polonium nucleus discharges an alpha particle and becomes lead. A curious fact about the radium E emission is that the electrons emerge with various velocities. One atom will shoot out its electron with an energy of half a million electron volts, another with that of a million volts, others with still higher velocities. As a result of these subtractions of varying amounts of energy from radium E nuclei, we should expect the resulting polonium atoms to have different energies and therefore discharge their alpha particles at different velocities. But no, the alpha particles all come off with a uniform energy corresponding to 5.5 million volts. It is as though several guns were loaded with different amounts of gunpowder, some having one pound, some two, others three pounds, and despite these differences in charge each gun fired projectiles of the same weight at the same velocity. Such a situation is unthinkable. It violates the law of conservation of energy. There is also in the radium E transformation a discrepancy in the property of the nucleus known as angular momentum. This angular momentum is called "spin," and it is measured in terms of a special unit of physics. An electron has a spin one-half this unit, whereas the change from radium E to polonium requires a subtraction of one full unit or some other whole number.

It was to resolve this scandalous situation that Wolfgang Pauli postulated the existence of the *neutrino.* He assumed that the neutrino is of extremely small mass, probably zero; that it has a spin of one-half; that it can carry energy of different degrees of magnitude, and that it moves at the speed of light. As radium E atoms break down to form polonium they discharge the excess energy in two fractions: one as the electron, the other as the neutrino, and the sum of the two is always the same. Thus a proper balance is preserved, and the residual nuclei are each left with the same endowment of energy. With its spin of one-half added to the electron's one-half, the neutrino hypothesis also conserves angular momentum. Attempts have been made to detect the presence of neutrinos by trapping their energy, but with no success. Nevertheless, many other atomic phenomena argue for the neutrino's existence. Several years ago K. T. Bainbridge and E. B. Jordan, working with the powerful mass-spectrograph at Harvard, discovered certain atoms of indium which had the same weight as certain atoms of cadmium. These atoms, which have the same weight but different chemical properties, are called isobars. Since they differ in total

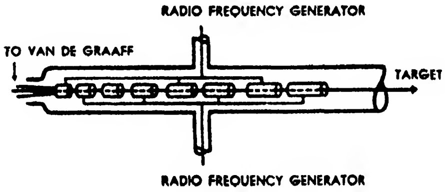


ELECTROSTATIC generator operates by building up charge and hurling its particles in one great bolt.

charge and hence in potential energy, one isobar would be expected to be unstable and to decay into the other by radioactive loss of energy. But both the indium and cadmium isobars are completely stable. The presence of neutrinos is believed to account for this stability.

Thus, in 1948, theory and experiment are offering, as the elementary units whose interactions account for the behavior of the physical world, at least nine particles of matter (protons, neutrons, electrons, positrons, five or more kinds of mesons) and two particles of energy (photons and neutrinos).

Can nature really be so complicated? May it not be that some, at least, of these particles are compounds of even more elementary building blocks? And, if so, what are the elementary ones? Do we already have them among the 11, or are there still finer and more elusive structural members beyond the reach of our instruments?



LINEAR accelerator impels particles by giving them several "kicks" as they pass down a series of tubes.

These are questions one overhears in the laboratories. They are questions for whose answers the cosmic rays are being intercepted and searched. Because of them more powerful accelerators are being built, more sensitive detectors, more accurate recorders.

II. Atomic Artillery

The alpha particles and other discharges from radioactive atoms, and the cosmic rays which continually bombard the earth from interstellar space, have been highly useful as research tools, but both are beyond the control of man. It was the desire to command the conditions of his experiments that led the physicist to devise his own artillery. He wanted to be able to choose the kind of projectile, to put more projectiles into a given barrage, and to regulate the velocity with which the projectiles struck their target.

Twenty years of inventive effort have been devoted to the problem, and several types of apparatus are now available. Each has its distinctive feature, but most of them may be grouped in two broad classes: the direct-voltage accelerators and the resonance accelerators.

In the direct-voltage machines, the projectiles move in straight paths through a long vacuum tube, impelled by the maximum voltage of the discharge. Examples are the *voltage multiplier* used by J. D. Cockcroft and E. T. S. Walton at the Cavendish Laboratory, and the *electrostatic generator* developed by Robert J. Van de Graaff at the Massachusetts Institute of Technology. Machines of this type are literally artillery pieces: barrels through which invisible bullets are fired at high velocity.

The resonance accelerators operate on a different principle. In them, projectiles are started at relatively low speeds and by the repeated push of periodic pulses of voltage are brought up to the energy required for the bombardment. Most of the resonance machines accelerate their projectiles in a whirling stream, swinging them around and around in circular or constantly enlarging spiral paths. Examples of these electrical slingshots are the *cyclotron*, the invention of E. O. Lawrence of the University of California; the *betatron*, developed by D. W. Kerst of the University of Illinois; and the *synchrotron*, first suggested in this country by E. M. McMillan of California and independently by V. Veksler of Russia.

There is also a resonance machine, the *linear accelerator*, which makes no use of the whirling principle, but sends its projectiles in straight lines through a tube, starting them slowly and building up to high speed by pulses of voltage added to the stream at equal intervals of time as it moves through the long barrel. E. O. Lawrence and D. H. Sloan developed the first linear accelerator about 14 years ago.

The energy of bombardment is rated in electron volts, a unit adopted to express the energy of the particles ejected by the radioactive atoms. The highest-energy projectiles obtained from spontaneous radioactivity are the alpha particles of 10.54 million electron volts (which hereafter shall be noted, in the physicist's shorthand, as "mev") discharged by thorium C'. This is a respectable energy, more than any accelerator was able to deliver until about the mid-1930's; but the bombardiers early realized that the search for the ultimate particles would require

many times this power. By the famous equation of Albert Einstein, $E=mc^2$, the binding forces which hold nuclei together could easily be calculated. These computations showed that to break the oxygen nucleus, for example, into its elementary parts 127 million electron volts would be required. It would take 487 mev to smash the iron nucleus, and 1.580 mev to disrupt lead.

THE first to project a machine in the class of more than 100 mev was E. O. Lawrence. After building several cyclotrons of progressively larger size and higher power, the inventor and his group designed one with a magnet having a pole diameter of 184 inches, and work on this 4,000-ton apparatus began at the University of California in 1940. The war interrupted its construction, and when building operations were resumed in 1945 the design was modified to apply a newly-recognized principle of frequency modulation. This change was introduced to make a correction for the relativity effect which makes particles increase rapidly in mass as their velocity approaches that of light. By varying the frequency of the pulsations of added voltage to correspond with the lagging rate of the more massive particles, the cyclotron was changed into a *synchro-cyclotron.* Since its completion in the fall of 1946, the synchro-cyclotron has abundantly proved its superiority to the unmodified cyclotron. Designed originally to operate at about 100 mev, the modified machine has accelerated deuterons to 200 and alpha particles to 400 mev. Bombardments with these projectiles have demonstrated the strange transformation of neutrons into protons, and have even manufactured mesons, as will appear later in this article.

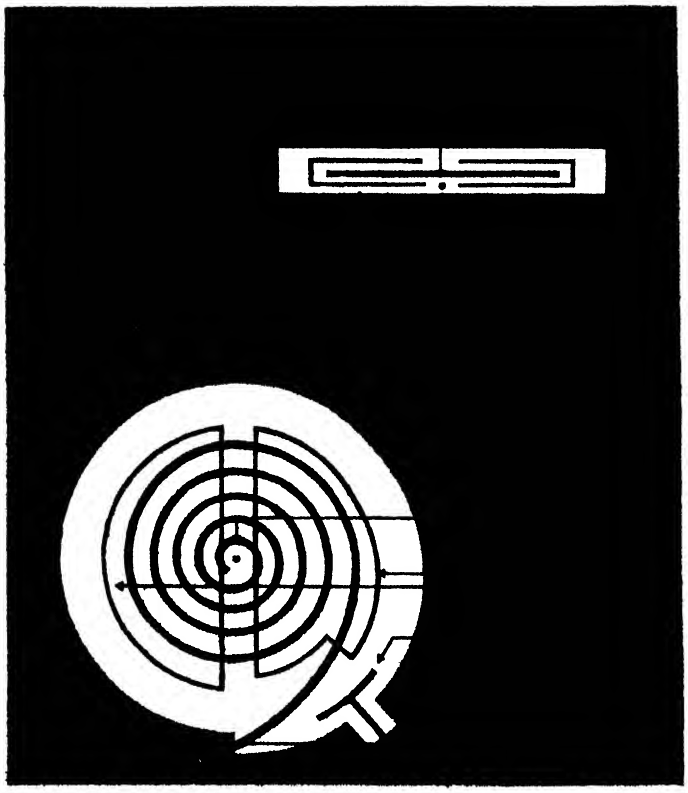
This 184-inch synchro-cyclotron at California is the most powerful accelerator now in use, but larger giants are coming. Most of them are proton-synchrotrons, an apparatus which accelerates protons through hundreds of thousands of small impulses. Whereas synchro-cyclotrons appear to have an upper limit somewhere around 750 mev, the synchrotron is able to build up voltages in the billions without disturbing the stability of the paths traveled by the particles or impairing the intensity of the beam. A 1,300-mev proton-synchrotron is under construction at the University of Birmingham, England; in the U. S one of 3,000 mev is projected by the Brookhaven National Laboratory on Long Island, and one of 6,000 mev by the University of California. These accelerators will provide projectiles comparable to those produced by cosmic rays. It is believed they may enable experimenters to create protons and neutrons.

III. Detectors

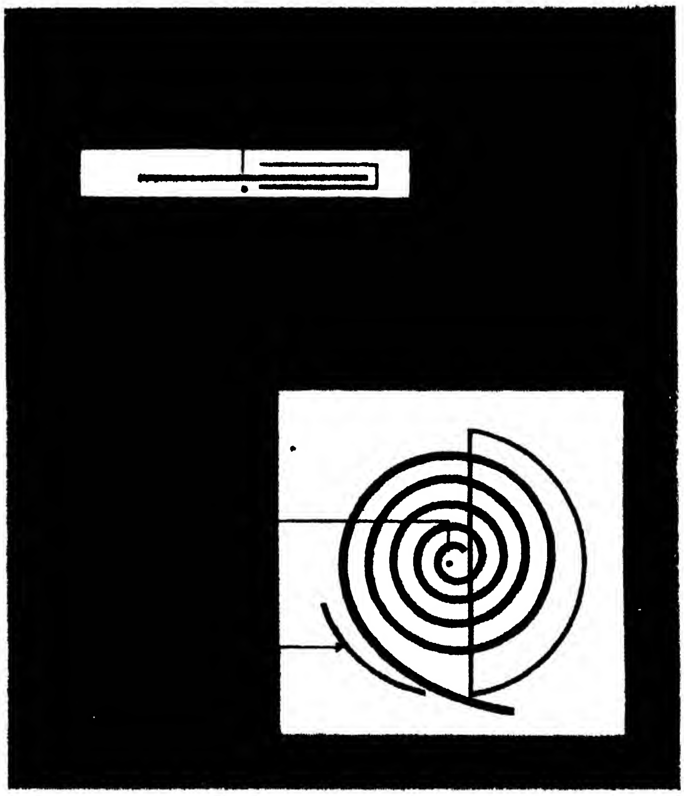
The targets of the gigantic artillery pieces of modern physics are unimaginably small. There are several methods of determining the sizes of nuclei, and they are in reasonable agreement in indicating that the atomic core is a globular or oblate structure whose volume varies approximately with its mass. The diameter of the hydrogen nucleus, the lightest, is $\frac{15}{100.000.000.000.000}$ of a centimeter, while at the other extreme, the uranium nucleus has a diameter $\frac{200}{100.000.000.000.000}$ of a centimeter. Thus the largest nucleus found in nature, although 238 times as massive, has a diameter only 13 to 14 times that of the smallest.

These dimensions are most difficult to visualize. If it were possible to enlarge the uranium atom until its nucleus became just visible, the nearest of its satellite electrons would be revolving in an orbit about six feet from that center; and beyond this orbit would be another, and then another—a total of 92 encircling electrons distributed among seven orbits. Imagine a solar system with 92 planets traveling around its sun, and yet one so small that it would take many billions to form a spot as large as the period at the end of this sentence.

Light has no wavelength small enough to form an image of these infinitesimals, and all that the physicist knows of their structure he gathers by inference from circumstantial evidence—the fingerprints,



CYCLOTRON accelerates particles by whirling them in the field of a powerful magnet. Each particle is pulled from one side of its orbit to the other by rapidly alternating the charge on the "dees." This machine is used to accelerate positively-charged particles.



SYNCHRO-CYCLOTRON extends the principle of the simple cyclotron to produce particles of higher energy. Its design, which embodies one dee instead of two, compensates for the fact that particles increase in mass as they are pushed closer to the speed of light.

footprints and other clues which the invisible particles leave behind. Many years ago he found that when the projectiles shot out of radium happen to collide with matter under certain conditions, the effects become visible. Since then the physicist has shown great ingenuity in inventing ways to trap matter under the conditions that show up these collision effects. Two arrangements are the Geiger-Müller counter and the Wilson cloud chamber.

The cloud chamber operates by a simple scheme in which the moisture-laden air within it is suddenly cooled by the withdrawal of a piston that expands the volume of the chamber. If a charged particle darts through the chamber at the moment of this expansion, droplets of the supersaturated vapor attach themselves to the air molecules which have been mutilated by collision with the particle, and thus the course of the speeding particle is revealed as a track of cloud. It is as though some invisible demon should plunge through a crowd and the police were to observe its path and estimate its force by the position and number of people knocked to the ground. The physicist is able to get additional information by placing the cloud chamber between the poles of a magnet. Negatively-charged particles then swerve in one direction, positively-charged in the opposite, and the radius of the curvature tells something of the mass of the particle. By installing plates of lead or other dense metals across the chamber, as barriers to slow the particles passing through them, it is possible to measure the particles' energies. The cloud chamber thus is an instrument of unusual versatility.

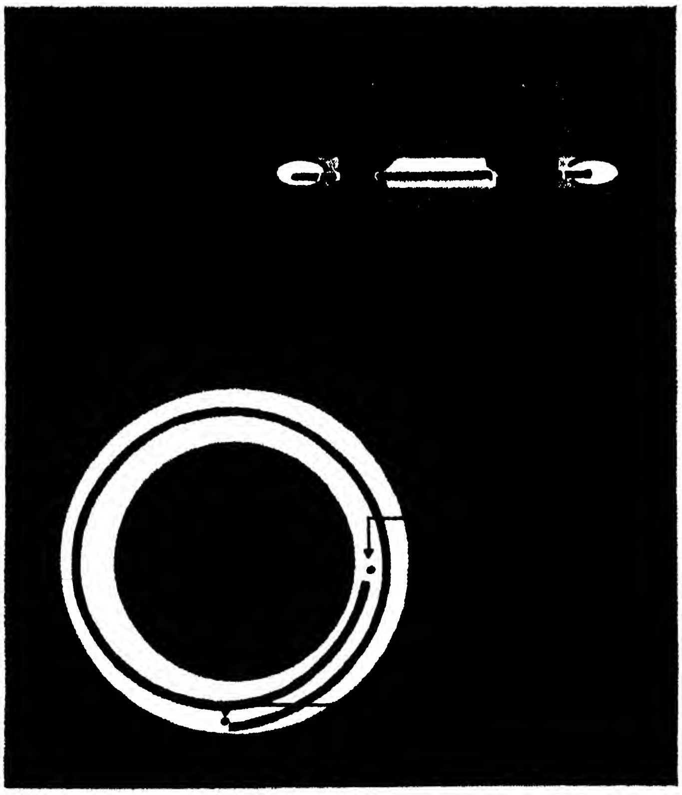
THE Geiger-Müller counter—an invention of two German physicists—reveals the invisible presence by another procedure, although its action also is based on the fact that a charged particle mutilates or ionizes the air molecules with which it collides. If these ionized molecules are positively charged, they will move to a negatively-charged electrode; if negatively charged, to the opposite. The counter is a trap to catch such occurrences. The minute electric current generated by the mutilations is amplified, and can be made to cause a click in a loudspeaker. Or the tiny current may operate a mechanical recorder, or cause a visible pulse on the screen of a cathode-ray tube. There are also other particle-detecting devices—fluoroscopes, electroscopes, specially prepared photographic plates with thick coatings of emulsion. It is by various means that physics has arrived at its present view of the nucleus.

IV. The Surrounding Vacuum

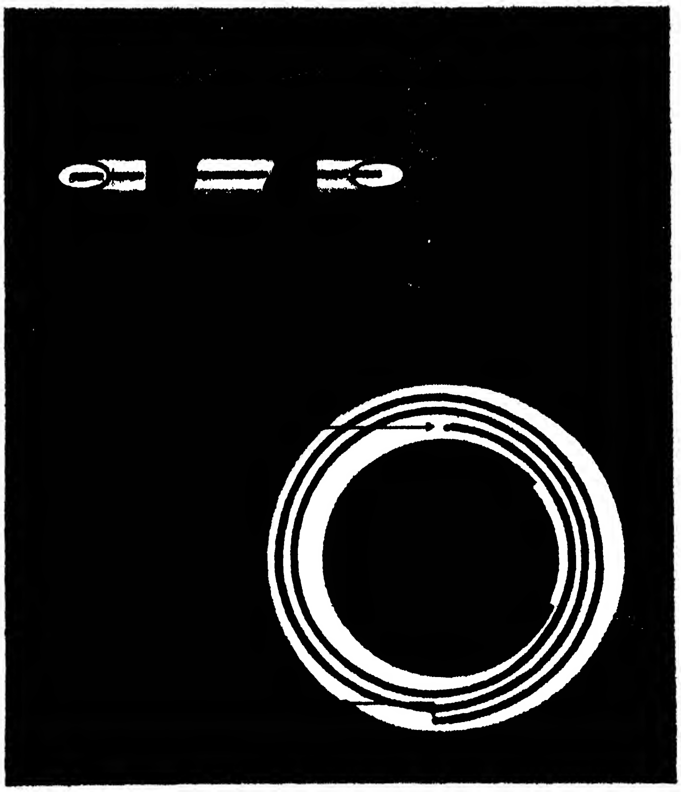
The microcosm of the atom presents a strange spectacle for the imagination. Between the nucleus and the orbit of the nearest encircling electron is a gap vaster in proportion to the sizes of these bodies than the space separating the sun from the orbit of the earth. This abyss within the atom is a perfect vacuum.

Occasionally, if the atom is of uranium, plutonium or some other radioactive species, a readjustment occurs within the nucleus and there is ejected an alpha particle, beta particle or the photon of a gamma ray. When that happens, the vacuum is of course momentarily crossed by the speeding particle, but these transits are rare and are so instantaneous as to be measured in billionths of a second.

Even a stable atom may occasionally suffer the accidental impact of a cosmic ray. If the hit is only a glancing one, it may provoke the nucleus to eject a particle; but if the blow is head on, the energy transfer may be so great as to smash the structure into fragments. Numerous photographs of such explosions have been taken in the course of cosmic-ray research, and more recently in cyclotron research at the University of California. These pictures show a burst of several tracks originating at a common center and radiating in many directions like the points of a star "Stars" of 20 tracks and more have been photographed, and each marks the path of a speeding nuclear fragment of some atom in the photographic emulsion that was blasted by the impact of a cosmic ray. Each fragment, as it moves away from the place of



BETATRON was developed to accelerate electrons rather than positively-charged particles. Whirled in a doughnut-shaped tube, the electrons are impelled by a changing magnetic field. They may then be used as primary bombarding particles or to generate high-energy X-rays.



SYNCHROTRON is also designed to accelerate electrons, although in the future it will also be used to accelerate protons. Like the betatron, it whirls its particles in a tube. Its fundamental design also enables higher particle energies than does the simple betatron design.

the explosion, is believed to function as a new nucleus, attracting to itself wandering electrons which become its satellites. Thus an exploded silver atom may become several nuclei of smaller mass and lower charge, each with its surrounding vacuum and attendant electrons.

The vacuum is a theater for the exchange and transformation of energy. Because of its proximity to the central powerhouse of the nucleus, tremendous electromagnetic forces play across this space, and amazing events can transpire there. If a high-energy photon, that of a gamma ray, chances to dart into the vacuum, the interaction of the photon with the electromagnetic field may create two particles, an electron and a positron. Cloud-chamber photographs have been taken of the tracks made by these pairs, both originating at a common point, with the path of the positron curving in one direction, and that of the electron in the opposite. This positron-electron pair is an example of the creation of matter out of energy. The nucleus gives up none of its mass; it serves only as a catalyst to provide a field of electromagnetism for the gamma ray to work on; the ray then surrenders its energy, which instantly reappears in the form of the two material particles.

There is, however, an even deeper underlying reality. Our account of the creation of positron-electron pairs is a rough-hewn portrayal of what is elegantly expressed in the laconic mathematics of P. A. M. Dirac's theory. This theory is concerned with the various states of energy which may be occupied by an electron. The number of such states is infinite. Plotted on a chart they stretch from zero upward, but the chart also points to an equal number of energy states below the zero line. It may strain common sense to speak of the energy of motion as less than nothing, but negative quantities have proved useful in mathematics and the concept must be admitted. The levels of less-than-zero are negative-energy states, but for simplicity (to avoid confusion with the negative electrical charge on the electron) let us call them minus-energy states, and those above zero, plus-energy states. The point is that a negatively-charged electron, any electron, can occupy either a state of minus-energy or one of plus-energy.

But electrons are lazy. Their tendency is to drop into conditions of lower energy, and this would seem to mean a general movement to levels below the zero line. However, there is a law, the Pauli "exclusion principle," which forbids more than one electron to occupy a given energy state; and consequently, after all the minus-energy states were taken, perhaps in some mad cosmic scramble at the beginning of time, there was nothing left for the losers but to accept the lowest available plus-energy states.

It is these electrons in plus-energy states that whirl in the orbits around nuclei, that flow through wires and other conductors to form electric current, that dance in the candle flame to generate light. Indeed, all the electrons that make up the perceptible universe are those which were forced by the exclusion principle into plus-energy states. The others, which presumably are more numerous, are comfortably at rest in their berths of minus energy—withdrawn from the dynamic world, buried in the vacuum.

But not completely unobservable, declared Professor Dirac. Theory told him that the chance blow of a gamma ray might knock an electron out of its minus-energy state. In that case, the hole left in the substratum should appear as a particle, a particle having the same mass as the electron but of opposite charge—in other words, a positively-charged electron. This speculation was published in England almost a year before the discovery of the positron. Since then hundreds of tracks of positron-electron pairs have been photographed. The tracks soon end, betraying the early disappearance of both positron and electron as free bodies. This is to be expected. For the electron is usually captured by some nucleus looking for another satellite; and as for the "hole," almost as soon as it appears the nearest electron leaps into it. Then both hole and electron disappear into the vacuum, and their energy darts off as radiation.

Such a picture is difficult to reconcile with ordinary logic. The region surrounding the nucleus was described earlier as a void. Now the same region is portrayed as the repository of innumerable electrons at rest in states of negative energy. Which is right? Can space be both empty and occupied? Apparently the two pictures represent different aspects of the same thing. Nature requires a perfect vacuum to serve as the sea of negative-energy states—and where all the negative-energy states are occupied, there is a perfect vacuum.

V. The Forces Within

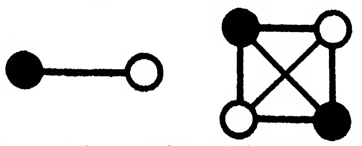
Some of the nucleus itself may be vacuum. If the particles which join to form it maintain their individuality as separate units, as seems probable, it is necessary to assume that there is space between them. Whatever its structure, the nuclear material is the quintessence of mass. Most of the world's weight is concentrated in these tiny cores. A cubic centimeter of platinum with its electrons weighs about three quarters of an ounce; but when the encircling electrons are peeled off and each atom is stripped down to its naked nucleus, we arrive at something that when packed together averages 130 million tons per cubic centimeter. And the same is true of all atoms, for nuclear material whatever its origin is "one stuff and betrays the same properties." The whole of Mount Everest might thus be packed into a cigarette case. W. D. Harkins has calculated that if all the matter making up the earth were collapsed down to its nuclear material, the diameter of our planet would shrink from its present 8,000 miles to about 1,080 feet—with no shrinkage in its weight.

Every particle known to the cloud chamber has been detected coming out of nuclei. Photons come out as gamma rays, electrons in the form of beta particles come out, and so do alpha particles, positrons, neutrons, protons, and mesons. In addition there is the hypothetical neutrino which the physicists assume must come out. Does this mean that the nucleus is a mixture of all these various particles?

The physicists don't think so. In the case of photons, for example, no one has ever seriously suggested that they are constituent particles. Gamma rays are created by the internal forces; when the forces reach such a state of imbalance that the nucleus must change to a lower energy, the shift is made and the surplus energy is ejected as a photon of gamma radiation. In the same way, it is now believed, electrons, positrons and mesons do not exist as components, but under certain stresses are created by the conversion of energy into mass. In this view, which is the prevalent one today, nuclei are composed of protons and neutrons—and nothing else. Protons and neutrons therefore are in a different class from the other particles: they are the nuclear building blocks, and because of this are called *nucleons.* All the other particles are by-products created by the interactions of nucleons.

INTERACTIONS are not likely to occur in the case of simple hydrogen, for its nucleus is a solitary proton. The first step toward complexity is the double-weight hydrogen atom whose nucleus, known as the deuteron, consists of one proton joined to one neutron. Helium is the next. Its nucleus is made up of two protons and two neutrons, and therefore represents the union of two deuterons. But the helium core is something radically different from the sum of two deuterons. Measurements show that the binding force which holds this heavier nucleus together exerts the power of 28.20 million electron volts, whereas the binding force of the deuteron is only 2.19 mev.

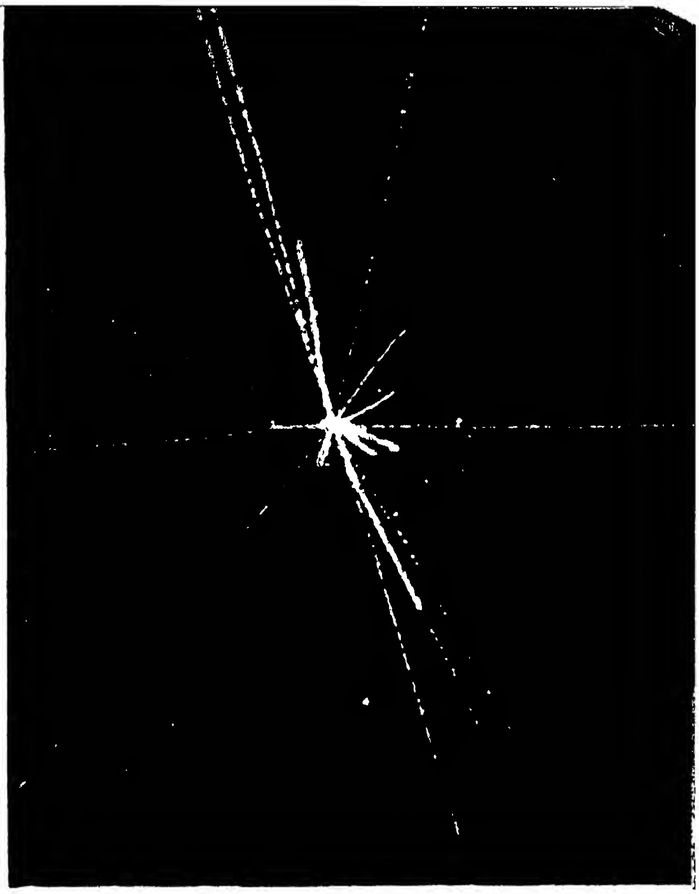
A reason for the higher binding force of the heavier nucleus has been suggested by Eugene P. Wigner of Princeton. In brief: the more nucleons there are, the



greater is the number of bonds holding them together. The accompanying diagrams, depicting the deuteron and the helium nucleus according to the number of particles, illustrate how this works.

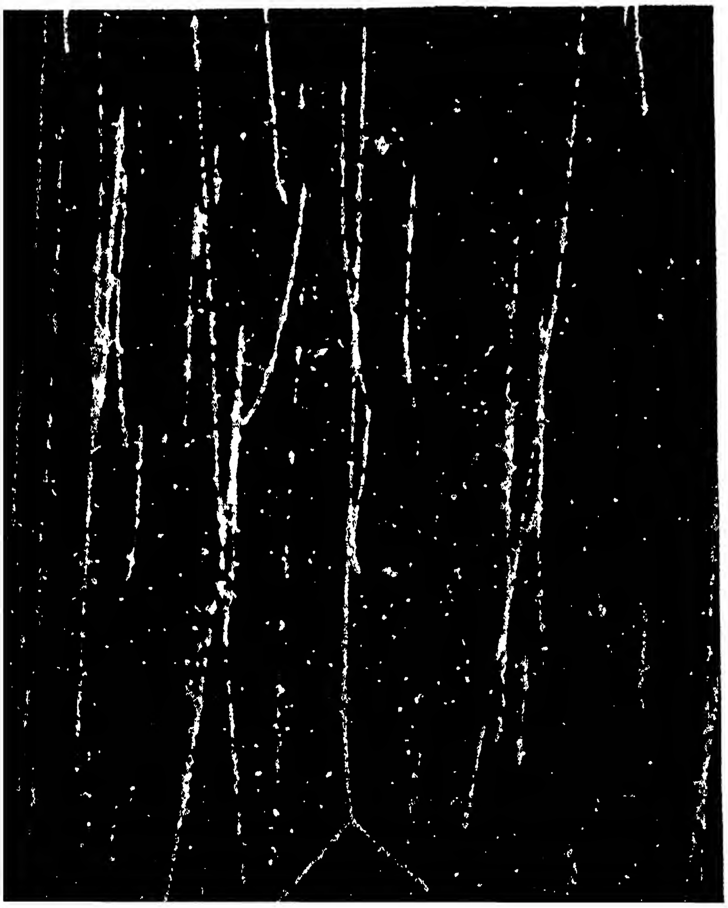
The nucleons of the deuteron, since there is only one bond between them,

PROTON, starting at upper left and ending at lower right, is deflected from three nuclei in special photographic emulsion employed in the study of particles.

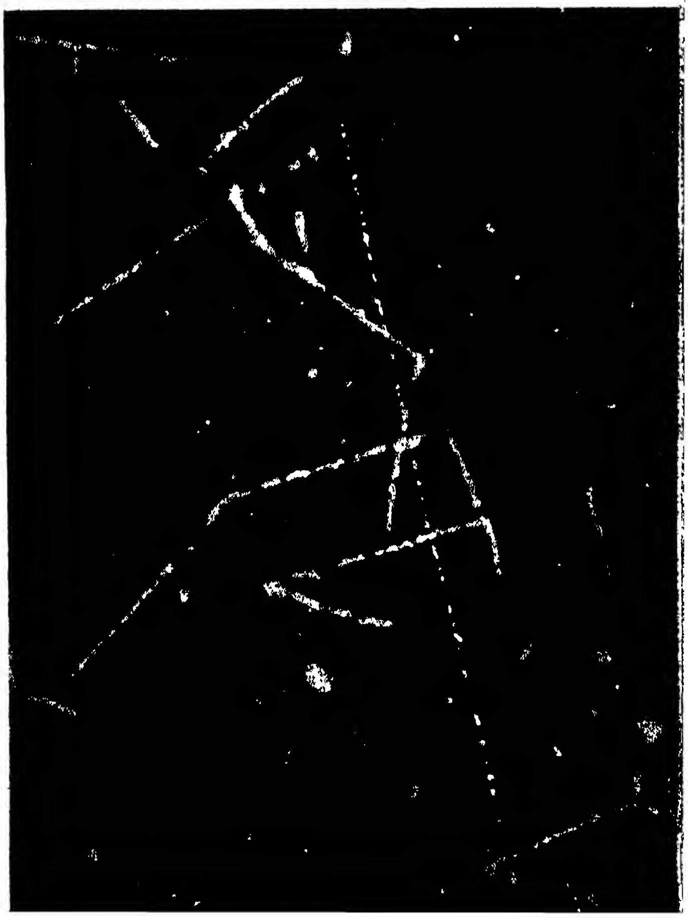


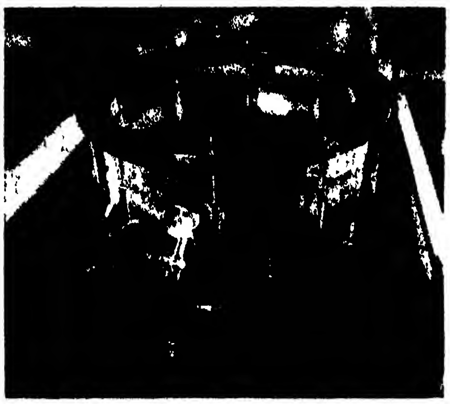
HEAVY NUCLEUS in the photographic emulsion explodes in a shower of heavy and light fragments when it is struck by a cosmic-ray particle of huge energy.

COLLISION of one proton with another is indicated by forked track at bottom. Bombarding proton is deflected at an angle; the other leaves a track in recoiling.



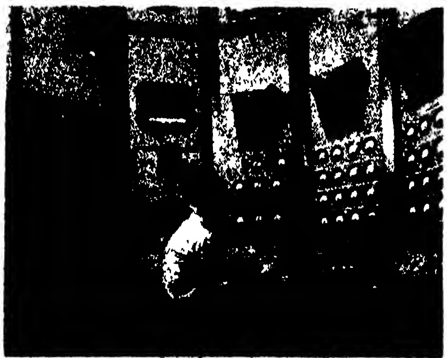
"STARS" of emitted particles are produced in emulsion when it is impregnated with radioactive thorium. Long track beginning at bottom is a recoiling proton.





CLOUD CHAMBER used with Berkeley cyclotron is lighted in quick flashes to permit track photographs.

CAMERA is put in place to make photographs of tracks in cloud chamber between poles of a magnet below.



CONTROL PANEL from which the Berkeley cyclotron is operated is observed by Physicist Luis W. Alvarez.

average one-half bond per particle; whereas, with six bonds joining its four nucleons, helium averages one and one-half per particle. The effect is to make helium a more tightly knit structure. Its nucleons draw closer to one another, and its mass becomes slightly less than the sum of the masses of two deuterons. This "mass defect," which one finds in all nuclei made of two or more particles, is highly significant, for it represents the amount of matter that has been converted into energy to provide the binding force.

The nature and mechanism of this binding force is one of the great mysteries. Indeed, the quest for the ultimate particles depends, in large measure, on understanding the binding force.

Gravitational attraction operates between particles just as it does between stars and planets. It is possible to calculate the magnitude of this force between two protons by applying Newton's law that gravity varies inversely as the square of the distance. In the close quarters of the nucleus this gravitational attraction of nearby particles for one another is considerable. But it is not nearly great enough to account for the tremendous binding forces of nuclei, ranging from 28.20 mev for helium to 1,780 mev for uranium.

Moreover, there is present in all these nuclei, from helium to uranium and beyond, a disruptive agency more powerful than gravitation. It is the force of repulsion which exists between bodies carrying the same kind of electrical charge. The mutual repulsion of proton for proton is so great that, according to Frederick Soddy's calculation, if a gram of protons could be concentrated at one point on the earth's surface and another gram at the opposite point on the other side of the globe, the repulsion of these two tiny positive charges for one another would be equivalent to a pressure of 28 tons This is at a distance of 8,000 miles! And yet within the confines of the nucleus protons dwell in such close communion that millions of volts are required to blast them apart.

It was this paradox that led physicists to assume the existence of a force of attraction which is able to overrule the electrical force of repulsion. They call it the *nuclear force*, since it is able to operate only over distances of very small magnitude, such as those within the atomic nucleus. Exact measurements of this force were made by, among others, Merle A. Tuve and a group at the Carnegie Institution of Washington, using the 1.2 million-volt electrostatic generator of the Department of Terrestrial Magnetism. They fired protons at hydrogen nuclei, and gradually increased the voltage until a speed was reached at which the momentum drove the projectile so close to the nucleus that it was attracted rather than repelled. This marked a boundary—the distance at which the nuclear force of attraction began to operate. By applying the principles of wave mechanics, a mathematical analysis of the experimental results was made by Gregory Breit, assisted by E. U. Condon and R. D. Present, and their calculation gave these findings:

1. The electrical force of repulsion ceased to control when the projectile proton got within about 1/12,000,000,000,000 of an inch of the target proton.

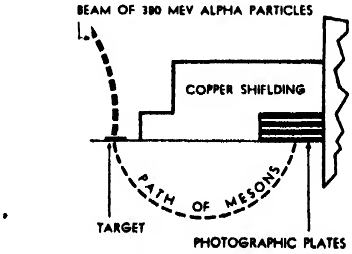
2. The nuclear force of attraction which suddenly took control at that distance was approximately 10^{36} times greater than the gravitational force between the two protons.

Experiment has shown that the nuclear force of attraction operates also between neutrons, and between protons and neutrons.

The nucleus, according to this testimony, is a powerhouse of opposing forces —an electromagnetic field and a nuclear-force field. One evidence that electromagnetic force operates within the nucleus is the emission of photons of gamma radiation. These photons are quanta of the electromagnetic field. But if the electromagnetic field is thus quantized in the form of a particle, may it not be that the nuclear-force field also has its particle? It was this question that led the Japanese physicist Hideki Yukawa to speculate on the existence of the meson some months before it was discovered in a cloud chamber

VI. Mesons

Mesons are the most baffling and unpredictable objects thus far glimpsed among the debris of bombardments. Not only were they discovered by means of cosmic rays, but they appear to constitute about three fourths of all the cosmic rays reaching sea level, the other fourth being electrons. They are not the primary cosmic rays that reach our atmosphere from outer space, but are secondaries knocked out of air atoms by the incoming primaries. Instruments sent to high altitudes in balloons indicate that most of the primary rays are protons. They travel with such prodigious energy that they are able to penetrate many miles into the atmosphere, mutilating atom after atom in a series of collisions. Meanwhile, the mesons and electrons knocked out of atoms by these



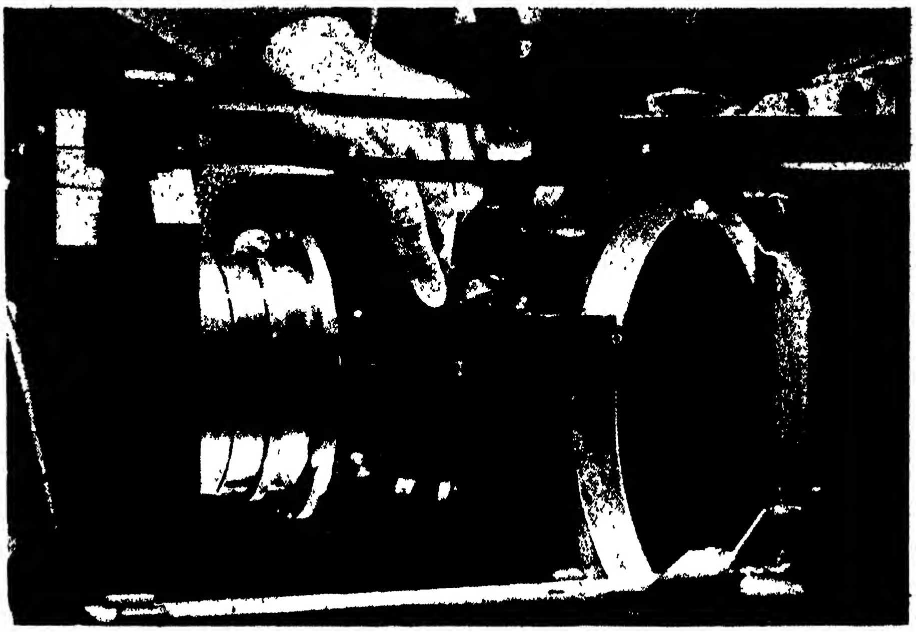
MESONS were produced and recorded in Berkeley cyclotron by bombarding carbon with alpha particles.

runaway protons may receive energies almost as great as those of the primaries themselves. There is evidence that some mesons reaching sea level plow into the earth with 100 million mev. for they have been detected in mines at depths of one mile. As they move at speeds close to the velocity of light, these high-speed mesons smash other particles out of atoms. One of them passing near an atomic nucleus and deviated by its electromagnetic field is thereby accelerated and caused to give off high-energy radiation in the form of a gamma-ray photon. This photon, by its interaction with atoms, may initiate a shower of electrons and photons, thus launching hundreds of particles as additional cosmic rays. Mesons appear singly, in pairs and in showers; and, as it has been stated earlier, some are negatively charged, some positively and some are neutral.

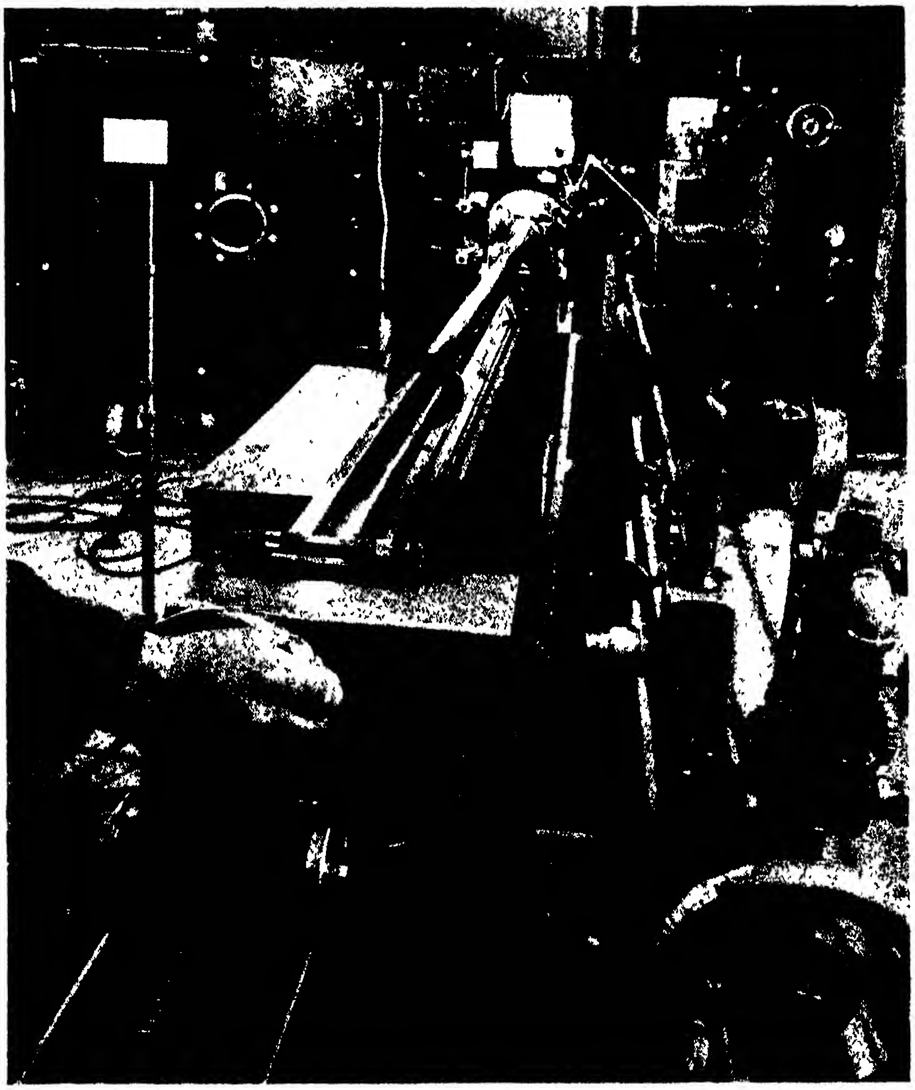
Until 1948 no one had been able to obtain mesons experimentally. But with the completion of California's 184-inch cyclotron an apparatus was at hand by which atoms might be battered into giving off these nuclear oddities. Early in 1948, Eugene Gardner and C. M. G. Lattes set up an experiment to see if this could be done. Lattes, formerly of the University of Bristol group, only a few weeks before this had joined the California staff, coming on a Rockefeller Foundation fellowship.

For the bombardment they used alpha particles. As the alpha particles emerged from the cyclotron at energies of 380 million electron volts, they encountered a thin sheet of carbon in the form of graphite. This was the target from which Gardner and Lattes hoped to hammer mesons. If any came out, the magnetic field of the cyclotron would bend their courses into curving paths that were calculated from their masses. This made it possible to put a stack of photographic plates across the expected paths. Mesons knocked out of the carbon should penetrate the emulsion of the plates and, by ionizing granules with which they collided, the mesons might photograph their own tracks. This was the logic of the experiment.

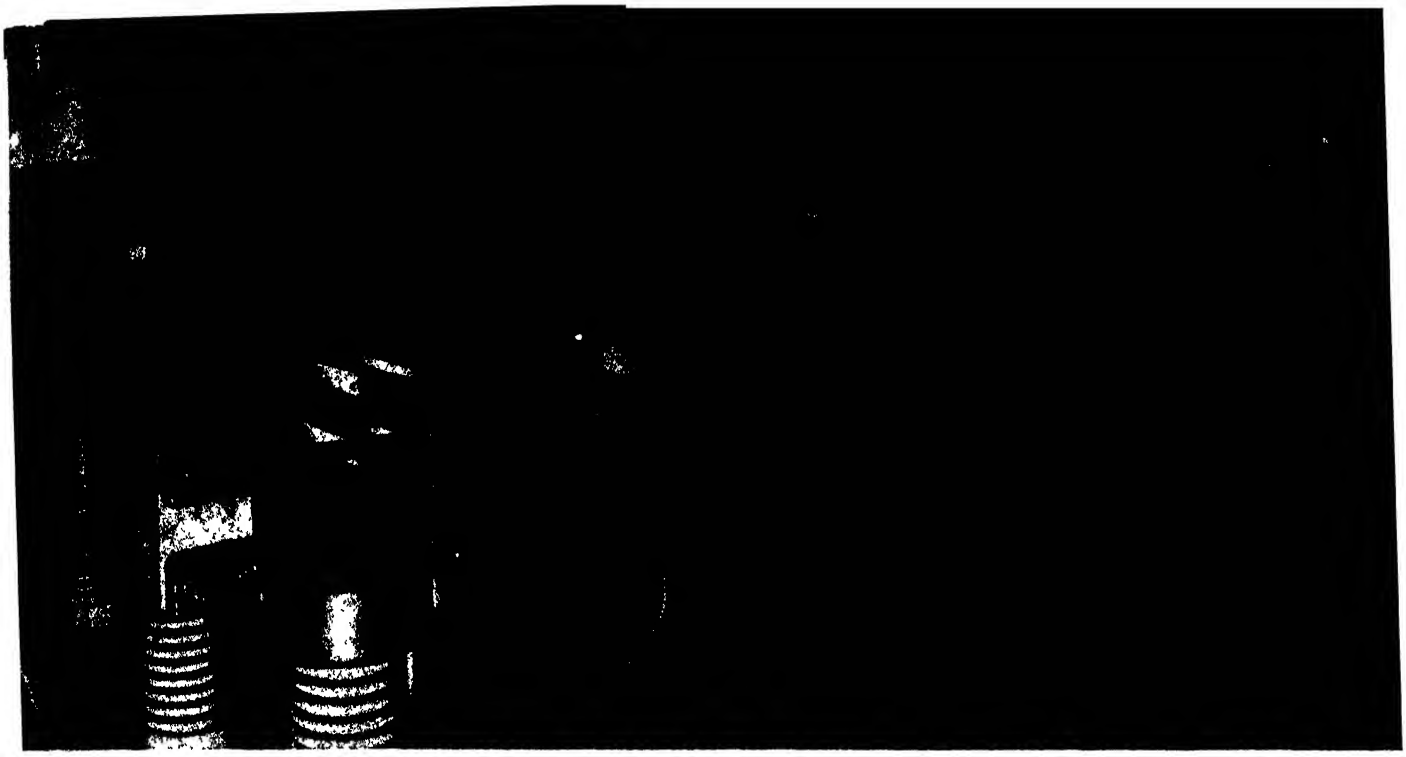
The photographic plates were exposed. Then, because of their thick emulsions, they were given 30 minutes in the developing fluid. And behold, the meson tracks became visible! There were hundreds of them. Indeed, 30 seconds' bombardment with the cyclotron gave 100 times as many mesons as Dr. Lattes had been able to photograph in 47 days of cosmic-ray observations in the Bolivian Andes last year. To be sure, the laboratory mesons were not as energetic as those produced by cosmic rays; their speed was that of a mere four mev. But under the controlled conditions of the laboratory it was possible to measure their masses quite exactly. The fact that the particles can be produced at will, and in such large numbers,



TARGET HEAD of the Berkeley cyclotron was especially rigged for the production of artificial mesons (*see drawing on opposite page*). Here packet of photographic plates is placed in slot. Carbon target is at tip of rig.



LONG PROBE is designed to facilitate the removal of radioactive targets after they have been bombarded in cyclotron. Targets are removed from the end of the probe and placed in lead-shielded carts by remote control.



INSIDE THE CYCLOTRON at Berkeley are the essentially simple parts that manipulate its various bombarding particles. Above and below are the 184-inch poles of its great magnet. Just below the upper pole,

makes this recent achievement in California the beginning of a new chapter in meson research. As larger and more powerful accelerators are built, we can look forward to mesons of hundreds and even thousands of mev energy.

PRACTICALLY all the mesons knocked out of carbon (and later out of beryllium, copper and uranium) by the cyclotron bombardment weighed about 313 times the electron mass. This corresponds rather closely to the mass of 320 reported by the University of Bristol group for the heavyweight mesons discovered last year in its cosmic-ray photographs; and perhaps the 313 mass measured in the laboratory is a more exact determination than that estimated from the photographs taken on the mountain top. It is assumed, therefore, that these particles of 313 mass which were knocked out of carbon by the cyclotron bombardment are the *pi* mesons discovered by the Bristol group in 1947.

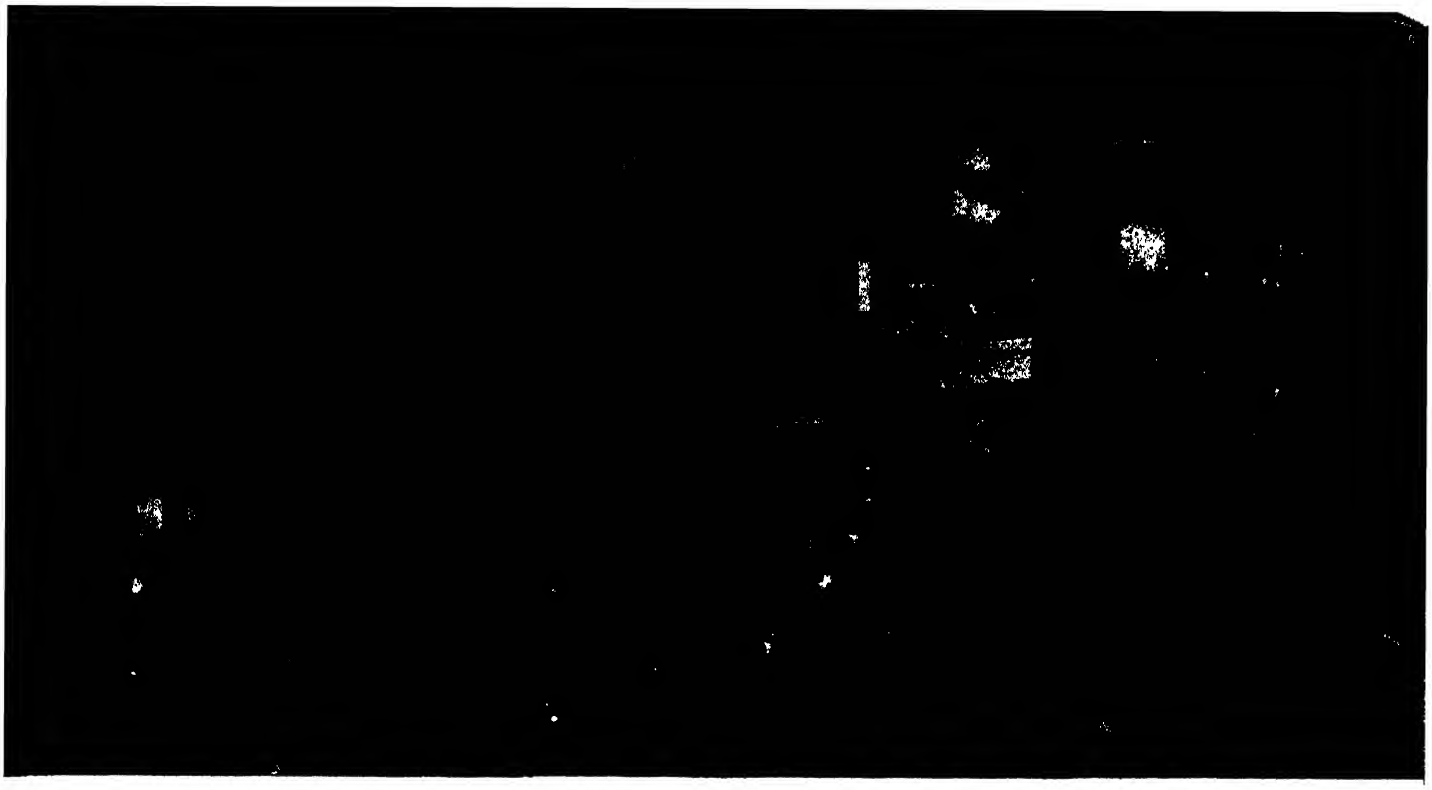
The photographs show that the heavyweight particle, the *pi* meson, has a remarkably short life—less than two millionths of a second—and what happens at the end of its existence depends on the electric charge of the particle. If the *pi* meson is positively charged, it travels a distance determined by its speed and then disintegrates into a positive *mu* meson, with the emission of a neutral meson of a mass of about 88.

If on the other hand, the *pi* meson is negatively charged, the positive charge of some atomic nucleus eventually attracts it, and the meson disappears into the nucleus which subsequently explodes in the familiar "star" effect.

What happens to the lightweight, the *mu* meson of 200 mass? Again, the end result depends on the electrical character of the particle. If it is positively charged, the *mu* meson decays into a positron, and the photographs provide data which suggest that a neutral meson and a neutrino are also released in the disintegration. If the *mu* meson is negatively charged, it is of course subject to the attraction of the positive charge of nuclei, and consequently the particle is captured by the first atom it encounters. The meson then begins to revolve around the atom's nucleus. According to studies by John A. Wheeler of Princeton University, the new satellite draws progressively closer and closer to the nucleus, cutting deeper and deeper into its interior, until suddenly the meson disappears. In the case of atoms lighter than aluminum this disappearance is heralded by the emission of an electron, with the release at the same time of a neutral meson and, presumably, a neutrino. In the heavier atoms, the meson simply vanishes with no perceptible emission or disintegration fragments—but it is assumed that a neutral meson is discharged, or a neutrino, or possibly both.

Of the state of mesons within the nucleus physicists know almost nothing, but

ARTIFICIAL MESON produced in the Berkeley cyclotron wrote its track in a pile of photographic plates which were then assembled in a mosaic. The meson enters the picture at upper left, darts through the emul-



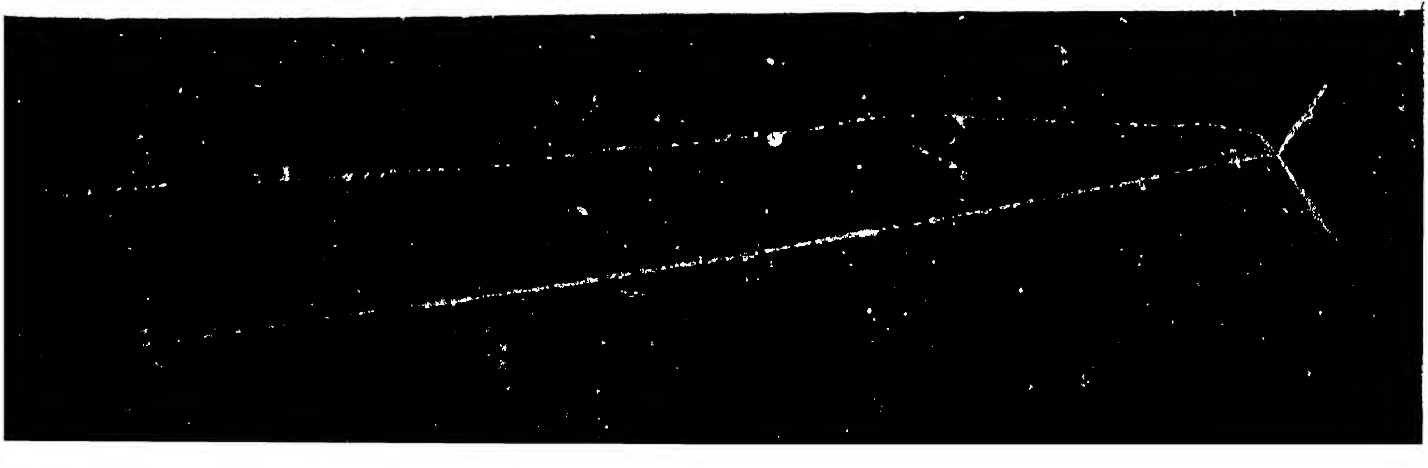
obscured by copper facings, is the cyclotron's single dee. At right one of Berkeley experimenters examines the end of the target probe. When the cyclotron is in operation, all this apparatus is sealed in vacuum tank.

an idea widely discussed portrays the particles as existing in the force fields of the constituent nucleons. According to this theory, the field of a neutron is continually interacting with the corresponding field of an adjacent proton and in these fields the electric charge is perpetually being exchanged, shuttling back and forth between proton and neutron in an eternal game of tennis in which the electric charge is the ball. The proton biffs its charge to the neutron, and thus detached from its charge becomes itself a neutron, while the neutron which receives the charge becomes a proton. But the recipient hardly gets the charge before it volleys it back to its former owner. Thus we have a picture of the atomic nucleus as a place where protons are continually becoming neutrons, and neutrons protons, with the charges in transit most of the time.

Several studies with the 184-inch cyclotron have demonstrated that an exchange of charge does take place. The experiment most directly proving this was conducted by Wilson Powell and Walter Hartsough at the University of California laboratory in 1947. They used 100-mev neutrons as projectiles, and fired them into a cloud chamber filled with hydrogen gas. Since the nuclei of the gas were all protons, whatever interactions occurred could be interpreted only as neutron-proton interactions. The momentum with which these 100-mev neutrons struck was gigantic. When a neutron makes a head-on collision with a proton in the cloud chamber, the force of the blow can be as high as 3.4 tons. This force, if it were exerted as an even pressure over one square inch of area, would equal the weight of 39,000 earths. While the neutron is being pushed by this force, its acceleration is 5×10^{27} times that of gravity. Thus propelled, the neutron approached so close to the proton that the distance separating the two particles was of the same order as that which prevails within nuclei. The results of the collision were interpreted from the subsequent behavior of the particles, and this indicated that in a large number of instances the charge was exchanged. At the moment when projectile and target were in close contact, the positive charge of the proton passed over to the neutron, and the latter darted off as a proton, while the former moved in a new path as a neutron.

While the cyclotron experiments show that the exchange does indeed take place, they reveal nothing of the mechanism by which the transfer is made. Whether or not the meson takes part in these interchanges, and carries the charge back and forth between the particles as Yukawa suggested, remains in the realm of speculation. The only objective evidence we have of mesons is their appearance as free particles shot out of nuclei as a result of high-energy collisions. These discharges are accompanied by changes in the status of the bombarded nucleus. Pre-

sion for about an inch and a half and is captured by a nucleus. This then explodes, sending one fragment back along the path of the meson. Capture of the meson by a positive nucleus indicates that it has negative charge.



MESON SONG

We have mesons *pi* and mesons *mu*,
And mesons that serve as nuclear glue.
We have mesons large and mesons small,
Plus charge or minus, or no charge at all.

Chorus: What! No charge at all?
No! No charge at all.
A very small rest mass,
And no charge at all.

Vector or scalar or halfway between,
Sometimes the convergence can scarcely be seen.
Two hundred, four hundred, nine hundred mass,
All sorts of charges in every weight class.

Chorus:

The forces exchange when at distances small;
There's the depth of the well and the height of the wall;
The quadripole moment a tensor demands
What very strange forces we have on our hands!

Chorus:

Oh Bose! Oh Fermi! Perhaps Einstein, too,
Send a unified theory for both *pi* and *mu;*
With spin and statistics, adjustable range,
Nuclear structure is yours to arrange.

Chorus: What! No sense at all?
No! No sense at all.
A very small rest mass,
And no sense at all.

sumably the emergence of a positive meson means that a proton has lost its charge, that the nucleus now has one more neutron than it had before; while the emergence of a negative meson signals the transformation of a neutron into a proton.

Current attempts to explain meson behavior can only be described as groping approximations. There is a song going the rounds of the laboratories which expresses some of the bewilderment that confronts those who experiment with and meditate on the new-found particles It was composed by a group of physicists and wives at a social gathering following a seminar on mesons led by George E. Valley at the University of Rochester last January. The "Meson Song" (*see box*) ends with the refrain:

What! No sense at all?
No! No sense at all.
A very small rest mass,
And no sense at all.

Perhaps many readers would agree that mesons make no sense at all. And yet these particles cannot be dismissed. Their evidence is all about us; they write their wriggly paths in our cloud chambers and photographs; they bombard us from all directions. While you have been reading this article, several thousand mesons driven by cosmic rays have plunged through your body.

VII. Theories

Many physicists are frankly dissatisfied with the complexity of nuclear theory. Some are testing daring new ideas in the search for a simpler and more unified pattern to describe the microcosmic architecture. At Princeton, for example, Dr. Wheeler and his group are considering the possibility that mesons, protons and neutrons may all be built up from electrons, positrons and neutrinos. It is a highly speculative suggestion which physicists view with cautious skepticism, as they do all new attempts at simplification. Dr. Wheeler himself points out that the idea must remain a question until there is fuller examination of electromagnetic and electron-positron pair theories. But he and his associates are definitely exploring the implications of a world built of electrons and positrons as the material units, with neutrinos as the energy units.

The electron-positron pair is the key to the concept. We know that when electron meets positron both are annihilated, with a release of gamma radiation. It has also been proved that the action of a gamma ray on the electromagnetic field can call a pair into existence. Imagine, then, a condition in which pairs of plus and minus electrons are continually being created and destroyed. Imagine these newborn and dying positives and negatives perpetually weaving back and forth within the nucleus, describing a network of paths, and by these movements generating the binding forces.

"It would be a gain if we could get away from the postulate of a special nuclear force," said Dr. Wheeler, "and account for the binding energy in terms of something we already know. Chemists used to imagine a 'chemical force' to account for the affinity of certain atoms and molecules for one another but as knowledge of the electrical structure of atoms advanced, the chemists came to see that affinity was simply a manifestation of electromagnetism. So we think it may turn out to be in the case of the nuclear force."

COSMIC-RAY research provides statistics that may have a bearing on this question. Counting devices indicate that among secondary cosmic rays the positive mesons outnumber the negatives about five to four. There are indirect indications that the primary rays which produce mesons in the upper atmosphere release about nine in a single collision. If we assume that a proton breaks up into nine mesons, the most likely order of fragmentation would be five positive mesons and four negative ones, the extra positive being the proton's charge.

The neutrino also may enter into some of the material particles. For example, a neutron, of mass 1,836 times that of the electron or positron, may embody 918 electron-positron pairs, but since each electron's spin of one-half unit would cancel out each positron's opposite spin of one-half, this would leave the neutron with no spin. By assuming that a neutrino enters into the structure, the neutron's actual spin of one-half is explained.

It would seem a great simplification to reduce the world to three elementary particles—two of matter and one of energy—with their interactions accounting for all the forces. But for the present the idea is only a conjecture, and whether or not it can fertilize definitive experiments remains to be seen. Of course, there is always the possibility that what Leibnitz called "the pre-established harmony" is beyond the reach of instruments, even beyond the reach of our imaginations. J. B. S. Haldane has given it as his opinion that "the universe is not only queerer than we suppose, but queerer than we *can* suppose." It isn't likely that many nuclear physicists will accept this doctrine of defeatism. They will continue their bombardments, their trapping of cosmic rays, their examination of the debris. The theorists will continue to follow up these experiments with their fascinating analyses, their rationalization of the results, sometimes with predictions of results to come. And eventually the strange assortment of protons, neutrons, mesons, electrons and positrons, with their accompanying photons and neutrinos, will take their places in a completely consistent picture. Such is the hope and the faith of science.

George W. Gray is a writer on scientific subjects.

VACUUM TANK of the Berkeley cyclotron surrounds the apparatus shown on pages 36 and 37. Sometimes a beam of particles is brought through the side of the tank. Neutrons are brought out through the hole in the plate at right center. They are then formed into a collimated beam by a hole in the concrete block in the foreground. Usually the cyclotron is surrounded by concrete shielding. Here part of the roof has been lifted.

SELF-PORTRAIT OF LEONARDO, who lived before medical knowledge had appreciably succeeded in the postponement of death, powerfully expresses man's sad acceptance of its inevitability. Leonardo died at 67.

THE

NOTHING in life seems more inevitable than old age and death. But this anthropomorphic fatalism springs from ignorance of the durability of living substances. Death is by no means a universal law of nature. The biologist observes that, while "all men are mortal," the same principle does not apply to all living things. Enough exceptions exist to encourage the hope that science may learn how to lengthen human life.

Consider fishes, for example. Fishes are not immortal. Their life span is limited by primitive dangers that are no less prevalent in the deep than in the jungle. Some fish die of mysterious poisons, such as the "red tide" that plagued the Florida coast last year. Some succumb to parasites that invade their internal organs, and some to the rasp-mouthed hagfish that bores into a flank and gradually devours the living host. Most fishes no doubt end their days in the jaws of their larger and swifter relatives. But there is one malady that fishes do not die of—old age.

Fishes do not die of old age because they do not grow old. Indeed, no animal "grows" old in a physiological sense. A growing organism is young. Only when the body reaches its adult size, and growth ceases, do the changes that we think of as signs of age begin to make their appearance.

But most fishes have no adult size. The tiny larval fish newly hatched from its egg capsule does not enter upon a fixed period of rapid growth up to mature size and strength. Its parents could not, if they had the minds to do so, anticipate a day of maturity when their offspring would be a fish among fish, ready to face the terrors of its watery world. Rather, the young fish continues to grow bigger and stronger as long as it manages to survive. The fact that fishermen always catch the "big ones" in the remotest lakes and streams, with no one around to see, is not necessarily a reflection on the veracity of the human race. Where fish are least disturbed by predators, including the human variety, they have time to grow big.

Although the age of many fishes can be read from annual rings formed in the scales, locating the oldest members of the fish population for study is obviously not

BIOLOGY OF OLD AGE

Senescence and death, which to man seem unavoidable, are not the rule among all species of living things

by Florence Moog

an easy job. So it is not surprising that we cannot say with certainty how long fishes live. Our best evidence indicates a life span of nearly a century for a few relatively well-known fresh-water species—pike, carp, catfish. Of the ages attained by deep-sea fishes, almost nothing is known.

For the purpose of determining how close living things can approach to immortality, plants, thanks to their habit of remaining in one place, make better material than animals. Some plants, of course, lose their young growing tissue after a period

BALD CYPRESS of Tula, in Mexico, is 52 feet through and probably the oldest living thing in the world.

of development and soon die. But others continue to grow by annually producing fresh buds and shoots, and such plants apparently live until disease or want of food or cold or drought or storm put an end to them. Many trees survive for centuries and some for thousands of years. Perhaps the oldest living thing is a great bald cypress which is still growing near the town of Tula in central Mexico. With a trunk 52 feet in diameter, this tree may have been 1,000 years old on the date when Jehovah is reported to have created heaven and earth.

The only true immortals, however, are the microscopic, one-celled organisms—algae, fungi, protozoa. These tiny organisms grow to a maximum size, then divide to produce two identical individuals which share the parent's protoplasm between them. The daughter units, if conditions are favorable, grow and divide and grow and divide, again and again. With no limits set on their growth, many of these creatures do not experience "natural" death. An isolated amoeba was observed to undergo 200 successive divisions and was still multiplying merrily when the experiment was terminated after 13 months. A culture of green algae was reported to be in good condition after having produced 1,300 generations in five years. In 1943 a protozoan culture raised by L. L. Woodruff of Yale completed its 37th year of continued growth. In that time it had passed through 20,000 generations. Of course not all the individuals produced were allowed to survive; if they had been, the entire surface of the earth would have been much too small to accommodate them!

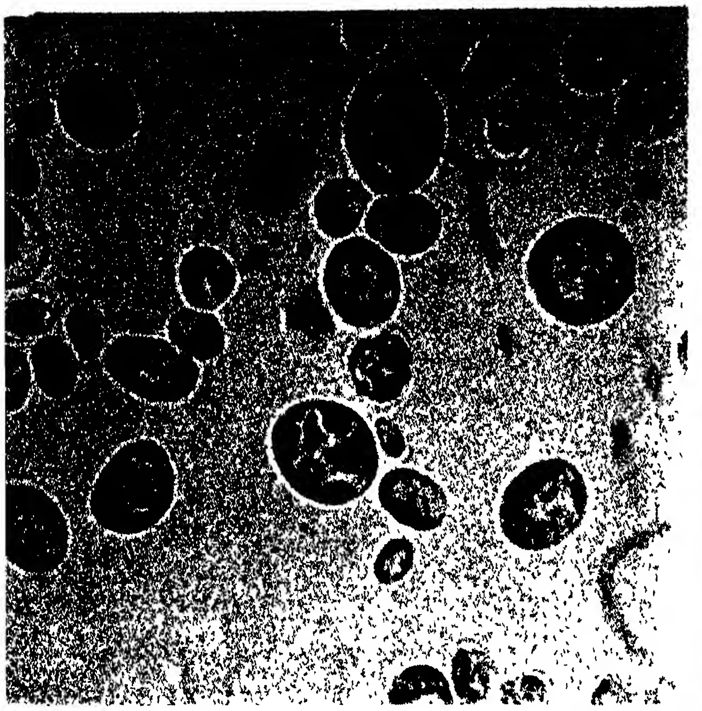
Given conditions under which growth can go on, even living material that ordinarily ages and dies will remain young far beyond its normal term. At the Rockefeller Institute in 1912 Alexis Carrel removed a bit of heart tissue from a chick embryo and immersed it in a nutrient solution of foodstuffs extracted from embryos. Trimmed at intervals and provided regularly with fresh nutriment, this tissue lived and grew until the experiment was deliberately ended in 1946. A chicken hatched in 1912 would have died 20 years ago, yet there is no reason to suppose that this snippet of heart need ever have died.

The young-old rats that C. M. McCay raised at Cornell a few years ago provide a no less striking, if not so durable, example of the age-resisting power of growth. Ordinarily a rat reaches full growth and maturity in four months. At two years he is elderly, and, unless he is a very exceptional rat, he dies before the age of three. McCay found that by feeding a diet sufficient in vitamins and minerals, but deficient in calories, he could stretch the growth period from four months to as long as 1,000 days. In one experiment the last withered survivor of a normally-grown group died at 965 days; at that age the retarded animals were bright young adolescents. When the slow-growing rats at last came close to the normal adult size, however, growth ceased. Age then proceeded to overtake the group, the last retarded animals dying at about four years. So the degenerative changes of age, it seems, can be staved off only so long as the achievement of maximum size can be held in abeyance.

Having a determined maximum size seems to be the condition of mortality among living things. Land animals cannot escape this condition, since on dry land the strength which living material can attain puts an outside limit on size. A whale may reach a weight of 140 tons; beside such a mass a five-ton African elephant is a pigmy. Yet the bulk of the elephant probably comes close to making the greatest demands that living bone and connective tissue can satisfy, for our rich fossil record discloses but one true land animal that was bigger than the modern elephant. An animal that grows to a "whale of a size" has to reside in a denser medium than air. In air, the bones of a whale-sized behemoth could not support its weight.

THE inexorable mathematics of dimensional change also contributes to making unlimited size a luxury beyond the means of land-living forms. An increase in size, particularly among mammals, entails a change in shape. A leggy foal does not become a full-grown horse merely by enlarging, nor does a baby simply elongate into a man. Form needs to change during growth because as the linear dimensions increase, the weight goes up at a much faster rate. Doubling the length, width and thickness of a two-pound book, for example, would produce a book weighing not four pounds but 16. If an 18-inch, seven-pound infant became a six-foot man by uniform enlargement in all directions, he would weigh 448 pounds! So it is not surprising that nature has resorted to the device of continually altering form to keep a growing body within manageable proportions.

If shape is to vary as the organism increases in size, the skeleton, and particularly the joints, must remain alterable as long as growth continues. But plasticity and strength do not go hand in hand. A young, developing joint is not so strong as a mature one that no longer grows. This is apparently one reason why, among the more active and venturesome types, evolution has favored those which grow rapidly to a fixed adult size. If such forms



ONE-CELLED ORGANISMS, which reproduce by dividing, are the only true immortals. Because they constantly grow and divide, technically an individual never dies. The example is *Chlorella*, the common green alga.

FISHES appear not to age in the same sense as land animals. They die from violence or disease. Above is a scale from the sand flounder *Lophopsetta aquosa*. Its age, measured by intervals in scale rings, is four years.

can maintain their mature strength long enough to reproduce themselves adequately, from nature's point of view they are "made." In the struggle for existence it does not matter how soon after the reproductive period death occurs.

One-celled forms escape the penalty of maximum size by halving themselves whenever they reach it. Trees evade the penalty because, not needing to support and move masses of soft tissue, they can keep on growing. And fishes are similarly exempt. Since the support of weight is no problem in the sea, all that fishes need is a reasonably firm backbone to enable the body to cut through the resisting water. They can grow steadily by simple enlargement, and so they do not grow up and they do not grow old. But animals that have learned to lead an active life in a medium of thin air have all foregone the advantages of unending growth.

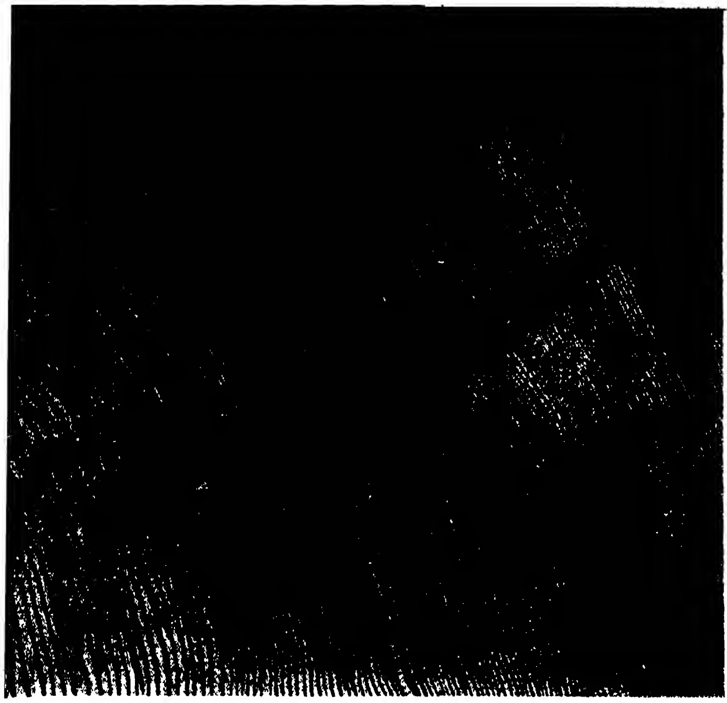
A limited size thus seems to be the price we pay for the privilege of living on land. But is aging an inevitable part of that price? Must senescence and senility always follow the attainment of mature size? Biologists and non-biologists alike have speculated on these questions since the time of Aristotle. Numbers of theories, of more or less pragmatic value, have been invented to account for senescence. The exhaustion of a "life ferment," the "starvation" or "wearing out" of tissues, have been suggested, though it is difficult to find an exact meaning for these terms. The disappearance of germ cells has also been offered as a cause of age, though there appears to be no necessary correlation between presence of germ cells and aging. The gradual "poisoning" of body tissues by putative toxins emanating from the colon is a perennial favorite among hypotheses. Its adherents have advocated as preventives of aging everything from the drinking of sour milk to the removal of the large intestine.

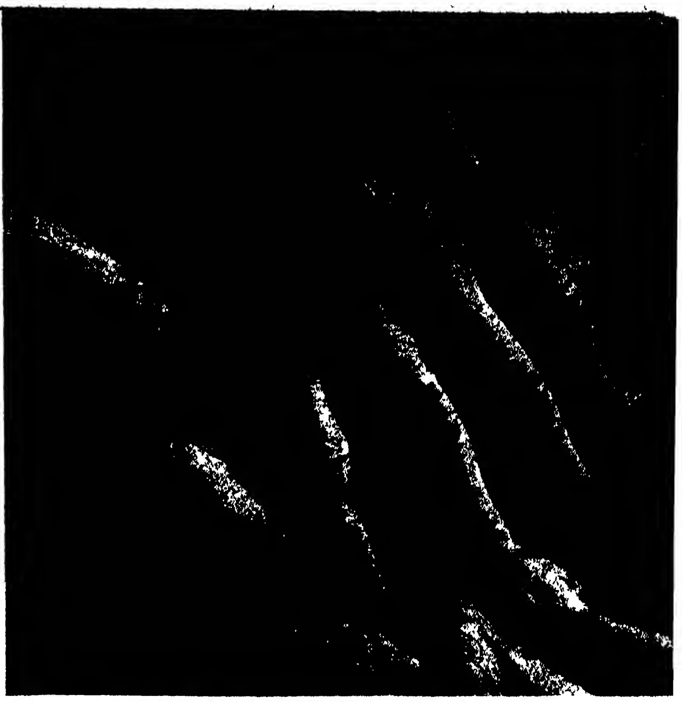
THE antithesis between growth and age has not proved easy to understand. When cells divide, as they do in growing tissues, the nuclei, in which the controlling agents or genes of the cells are located, break down, and nuclear materials flow into the general cellular substance. When divisions cease, this sort of interchange ceases too. Is this lack of nuclear-cytoplasmic mingling, then, the cause of aging? That it is a contributing factor is generally believed. But if it is a factor, it is not a hopeful one. The extent to which any tissue will divide and grow is determined by heredity and is not subject to alteration. And even if it were possible to make growth go on without limit, the effect would hardly be desirable.

Cessation of growth, however, does not now seem to be as calamitous as it seemed in the days when it was taken to mean that tissues become static. Ten years ago the body was still often described as an internal combustion engine that takes in fuel but not substance. But in the middle 1930's Rudolf Schoenheimer and a group of co-workers at Columbia University's College of Physicians and Surgeons launched a radioactive-tracer study of the traffic that goes on among body constituents. By determining the fate of "labeled" substances which were fed to experimental animals, Schoenheimer was soon able to demonstrate that long after growth has stopped the structural materials of the organism are in an endlessly unsettled state. If a labeled protein building stone is fed to a rat on Tuesday, it will by Thursday be found incorporated into proteins all over the body, even in such apparently inactive structures as tendons and ligaments. Fats are just as unstable; in tissue fats and in fat deposits alike there is a restless fitting in and throwing out of molecules. Not even bone appears to be satisfied with its structure. If radioactive phosphorus is fed, the largest part of it finds its way into the bone salts of the skeleton, and, within a month, finds its way out again.

So the body is just as much in process of construction when size increase has stopped as when it is proceeding. That fact takes care of the old fear that mature organs must inevitably "wear out" or exhaust their "vital reserves." Yet the body does become old. With the passage of time, tissues become drier and infiltrated with fat, blood vessels harden, muscles weaken, bones grow brittle, eyes and ears gradually fail. Apparently the processes of self-renewal fall ever shorter of maintaining the efficiency of youth.

The pressing—and promising—problem for the immediate future is to determine the factors underlying the gradual decline of self-renewal. Two possibilities, which are not mutually exclusive, exist: 1) the failure may be in the biochemical apparatus that is designed to synthesize the material out of which the body is constantly remade; 2) it may lie in the apparatus for burning materials and obtaining energy from them. In the former case, the body cells would in time become "worn"; in the latter they might become choked with abnormal waste products of incomplete metabolism. In either case the real failure would involve the indispensable biochemical agents called enzymes.





TREES, like fishes, do not die of old age because they are constantly growing. The bald cypress of Tula (*page 41*) may be several millennia old. Shown above are the rings of a commonplace specimen of the Douglas fir.

MAN, like other land animals, degenerates independently of violence and disease. His skin wrinkles, his arteries harden, his joints stiffen. These processes lead to the ultimate physiological failure that causes death.

Enzymes are complex chemical molecules which, though present in the minutest quantities, take our inert foodstuffs in hand and manufacture living tissue out of them. Without enzymes no vital process could continue. Their depletion could readily explain the phenomena of senescence. So far interest in biochemistry has centered on what enzymes are present in various parts of the body and how they operate, not on how they change with age. The few pieces of work which have been done, however, do indicate that in mammalian tissues the passage of time brings about a lowering of enzymatic efficiency. Thus the body decays in much the same way that a mansion falls into disrepair because of a want of servants.

From both a theoretical and practical point of view, evidence of a lowering of enzymatic efficiency after the close of the growth period is important. Theoretically it promises to help us toward complete understanding and ultimate control of age deterioration. Practically it suggests a means right at hand whereby the rate of aging may be held to a minimum. This means is nutrition. Since the days of Horace, writers have praised the value of a temperate diet for continued health. Not even starvation has wanted its advocates. The sixteenth-century Venetian nobleman Luigi Cornaro, in poor health when young, adopted a diet of less than 12 ounces of solid food per day, and at 91 wrote a book recommending his regimen.

NOW that we understand something of the biochemical machinery that runs the body, we can appreciate why it is wise to refrain from overburdening this machinery with more food than it is equipped to handle. Too many calories in the first half of life may be a major cause of premature impairment of sensitive areas—joints, kidneys, heart and blood vessels. Obviously we shall never apply to human beings the technique of greatly prolonging growth through underfeeding that McCay used in rats. But the day may come when mothers will be persuaded that making junior expand at the fastest possible rate is not quite the highest achievement of motherhood.

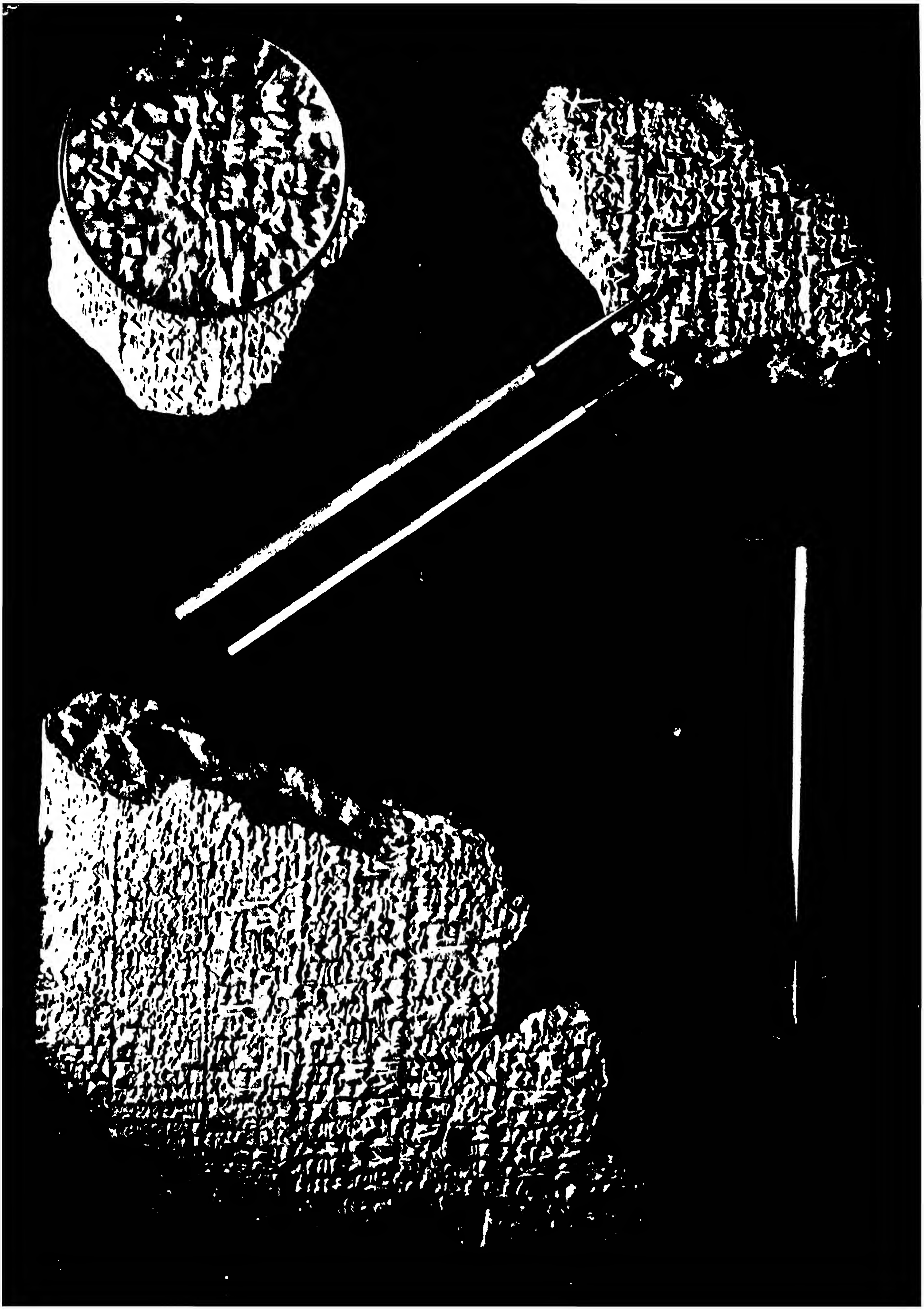
More important than calories in the diet are vitamins and minerals. Only a decade ago the importance of these accessory food factors was obscure, and not always taken seriously. Now we know that they are building stones of enzymes. Without an adequate supply of vitamins and minerals, enzymes cannot renew themselves, and they fall behind in their jobs. If deficiencies are severe, characteristic symptoms soon develop—nervous disorders, eye inflammations, bleeding joints, rickets. If deficiencies are slight but long-continued, do the effects accumulate into the disabilities of premature age? No research on this problem has yet been undertaken, unfortunately, but the possibility seems likely. Pending further information, a varied diet, well supplied with foods naturally rich in vitamins, remains the best kind of long-life insurance on the market.

Within the last 10 years scientific interest in the problems of aging has been gaining momentum rapidly. This interest comes barely in the nick of time, for the disorders of premature and pathological age—arthritis, nephritis, cardiovascular disease—have become a tremendous problem. Currently these disorders kill 800,000 Americans every year and reduce hundreds of thousands more to invalidism. If those who are now young are to be saved from swelling these ranks, some means of preventing abnormalities of the aging process must be found.

As medicine has learned to cope more effectively with the diseases of childhood and early maturity, the percentage of our population in the older age groups has been mounting steadily. Today close to 30 per cent of Americans are over 45; in 1980, according to estimates, the percentage will have risen to 40. So the second aim of age research must be to defer the age of senility. Already modern living conditions have brought about some progress in this direction. Surely few people nowadays would consider it necessary to "resolve," as did the lady in Dryden's play, to "look young till 40."

HOW far deterioration and natural death can be pushed back is still a matter of debate. Most conservative physiologists would grant that health and vigor can last to the age of 100. The enthusiastic Russians, who have recently been probing the secrets of age with great energy, would set the limit above 150. Verdi composing *Falstaff* at 80, Edison taking out his 1,033rd patent at 81, Oliver Wendell Holmes in service on the Supreme Court bench at 90, Titian painting *Christ Crowned with Thorns* at 95 are only a few of many authenticated examples that show that years alone need not dull the highest powers of the human organism. What nature can do for some, science can learn to do for all.

Florence Moog is assistant professor of zoology in Washington University at St. Louis.



"IF A SLAVE GIRL FLED . . ."

Being an account of how the law code of Lipit-Ishtar, a Sumerian king who ruled 19 centuries before Christ, was found to antedate the code of the great Hammurabi

by Francis R. Steele

AMERICANS are often described as megalomaniacs whose chief desire is to construct or own the fastest vehicle, the tallest building, the most expensive painting or the fattest bank account. Perhaps this description contains a particle of truth. If so, it is ironical that for almost half a century America has been the possessor of a superlative treasure of which it has not even been aware. This prize, only recently discovered in a dusty archaeological storeroom, consists of a handful of ancient Babylonian clay fragments that were originally unearthed nearly 50 years ago at the site of ancient Nippur. Now deciphered, these priceless tablets turn out to be one of the world's two oldest law codes. (The other, just reported from Iraq, is said to be a generation or two older.) The tablets show that history's first great law codifier was not Hammurabi, as long supposed. An earlier Babylonian king named Lipit-Ishtar wrote a law code which preceded Hammurabi's by a century and a half.

News of this possession, though hardly likely to evoke a general celebration, is nonetheless of considerable interest to others besides archaeologists. The average man understandably lacks a highly developed appreciation of such an exotic thing as a law code. His interest is awakened only on such occasions as he is accused of an infraction of the local Motor Vehicle Code and finds it necessary to pay for his experience, or when he is forced to grapple with the intricacies of a tax or price code. By and large he is content to leave the law to barristers. Yet the history of law is the history of society, and everyone interested in that history is familiar, at least by name, with the works of a few of the greatest lawgivers: the *Corpus Juris* of Justinian, compiled in 529 A.D.; the Hebrew laws of Moses, laid down in the second millennium B.C., and the celebrated code of King Hammurabi, inscribed in Babylonian cuneiform at the beginning of the seventeenth century B.C. Discovery of the law code of Lipit-Ishtar, to which Hammurabi was indebted for parts of his code, now sheds new light on the origins of human law.

THE LAW CODE of Lipit-Ishtar was written in cuneiform on a tablet 11 inches high and nine wide. Of it four small fragments remain, two of which are glued together. Here the fragments are arranged in the positions they occupied in the original.

Our knowledge of the history of early Near Eastern civilization depends in large measure upon the inscribed records unearthed by the modern excavator's spade. These records stretch back to the close of the fourth millennium B.C., when the Sumerians invented a simple pictographic system of writing. This simple script was soon modified and developed into the complex yet more flexible syllabic cuneiform script in which the writings of the great Babylonian and Assyrian Empires were cast. The earliest documents reveal to us a highly intricate society with detailed regulations for family relations, commerce and government. The picture is by no means complete, since only a small fraction of the original material has been recovered. Our knowledge grows as each new piece of information is added.

The reconstruction of the Lipit-Ishtar code rests chiefly on four small pieces of an ancient clay tablet. These four pieces were among more than 30,000 tablets and fragments dug up at the turn of the century in the famous Nippur excavations by a University of Pennsylvania group which made the first full-fledged archaeological expedition to the Near East from American shores. The curious fact is that the Lipit-Ishtar fragments were actually brought to this country at least two years before the Hammurabi code was unearthed, but their story remained undiscovered for many years after the Hammurabi stele (pillar) was accepted as containing the oldest law code.

The four fragments lay unnoticed among thousands of others from the Nippur expedition in the University of Pennsylvania Museum until the Museum decided several years ago to sort and catalog all the unclassified inscriptional material in its Babylonian collection. Similarity in script, composition and content suggested that the four pieces belonged together. They were evidently parts of a single original tablet. They appeared to deal with Sumerian law, but this in itself was not remarkable, since Sumerian laws had been found on previously discovered tablets. The significance of this particular tablet emerged only after a careful study and translation of the fragments.

One of the first hints that the tablet represented something more than a random collection of laws was the discovery that part of the text was in a style different from the rest. In the left-hand columns of two fragments, short literary phrases were recognized. Further examination revealed the names of the Sumerian gods Utu (the sun god) and Enlil (the chief god of Sumer and tutelary deity of Nippur). Then, in the next to last column of one fragment, an entire sentence was translated:

"Verily, in accordance with the true word of Utu, I caused Sumer and Akkad to hold to true justice. Verily, in accordance with the pronouncement of Enlil, I, Lipit-Ishtar, the son of Enlil, abolished enmity and rebellion."

The name of the king, Lipit-Ishtar, would not be expected in the text of a law. It was at once clear that this section must be the official epilogue of a complete law code. Later, part of Lipit-Ishtar's name was discovered in the first column of the reverse side of one of the fragments. It appeared to be part of a prologue. Confirmation of this hypothesis was soon forthcoming. Thorkild Jacobsen, director of the Oriental Institute of the University of Chicago, called my attention to a tablet in the Louvre Museum in Paris which had been published some years before by de Genouillac as *A Hymn to Lipit-Ishtar*. Jacobsen suggested that the Louvre tablet actually contained the prologue to our law code. This indeed proved to be the case; the text of the Louvre tablet fitted into our broken text. It had in all likelihood been copied from our complete tablet.

Thus it was established beyond question that we had a formal law code, which, like the later one of Hammurabi, began with a prologue and ended with an epilogue.

Its date in relation to Hammurabi's code can be fixed, with reasonable assurance, within a few years. Lipit-Ishtar's reign ended 129 years before Hammurabi became king of Babylon. Hammurabi erected his famous code stele no earlier than the 35th year of his reign. Hence Lipit-Ishtar's code is at least 164 years older than Hammurabi's and may be as much as 175 years older, since we do not know in which year of his 11-year reign Lipit-Ishtar compiled his code. Its absolute date can only be approximated, for we do not have exact dates for the kings of Babylon. Within the past few years new evidence has lopped several hundred years from the dates previously assigned to them; the accession year of Hammurabi, which in 1900 was reckoned as 2342 B.C., is now estimated as 1728 B.C. So from the current evidence we may roughly date Hammurabi's code in 1690 B.C. and Lipit-Ishtar's in 1865 B.C.

FRAGMENTS ARE ASSEMBLED in tablet reconstruction. About 400 lines of the original text have been recovered. Of this about half is written on these pieces, the rest on the copies made by students practicing cuneiform.

To prepare for the task of deciphering and translating the four Lipit-Ishtar fragments, it was necessary to study all the previously published examples of Sumerian law and become familiar with Sumerian style and legal terminology. I discovered that more than half of the previously known Sumerian laws came from three tablets, also in the possession of the University of Pennsylvania, which the Assyriologist Henry F. Lutz had published nearly 30 years ago. Since both the Lutz tablets and our code fragments had been dug from Nippur and appeared to date from approximately the same period, there was a presumption at least of some connection between them. Further study showed that a very intimate connection did indeed exist. When I began to copy and transliterate the texts of the new fragments, I soon discovered that they paralleled the Lutz texts verbatim at several points. Six points of contact where the two sets of texts overlapped each other were established. I found that by means of these clues all four of the code fragments could be placed almost exactly in the positions they had occupied in the original unbroken tablet. Thus the tablet was reconstructed, as the illustration shows, with gaps left for the missing text.

The size of the tablet was determined from the shapes of the fragments and comparison of the overlapping texts. It was found, for example, that there were 53 lines of text in the Lutz tablet between a given line in one column and the adjacent line in the next column of one of the code fragments, indicating that each column in the code tablet was 53 lines high. The curvature of the largest piece in the Lipit-Ishtar code (made up of two fragments that had been glued together) indicated that the midpoint of the complete tablet lay between the fifth and sixth columns from the left-hand side. It was therefore clear that the original tablet was 10 columns wide and had a total of 20 columns of text on both sides. Measurement of the average number of lines per inch and the average width of columns on the code tablet showed that the complete tablet was 11 inches high by nine inches wide.

THE Lutz tablets, while they paralleled sections of the code, were evidently not complete texts. How can they be accounted for? People do not ordinarily amuse themselves by copying sections of a law code. There is, however, an entirely plausible explanation. The city of Nippur, as we know from countless other records, was one of the chief cultural centers of Babylonia throughout its history. It had a large library of literary and historical records and a thriving scribal school in close association with this library. Hundreds of literary and historical texts have been excavated from Nippur. With these have been found hundreds of so-called school texts, in which we find sign lists and exercises written by pupils in the scribal school who were learning the cuneiform characters of the Sumerian and Babylonian languages by copying documents.

Since Nippur, as one of the chief cultural centers, must have possessed an official copy of the law code of Lipit-Ishtar, it is likely that students were assigned sections of the code to copy as exercises in cuneiform writing. If we may assume this much, we can surmise that the Louvre tablet represents a school exercise by a pupil who copied on the small tablet he was using only the code prologue, and that the Lutz tablets were written by students copying sections of the code as advanced lessons in writing Sumerian law. Fortunately for us, both the school copies and the code fragments were recovered, for otherwise we would have no idea of the size of the complete code tablet nor of the arrangement of the legal material within it. On the other hand, the scientific value of the school texts is materially enhanced by their association with the code fragments for, as a result, the laws they contain are shown to be part of a specific code from a definite period in history rather than an arbitrary selection of Sumerian laws at random.

The law code of Lipit-Ishtar probably consisted of some 100 laws, running to an estimated 1,200 lines of text. This is about a third the length of the Hammurabi code, which runs well over 3,600 lines and contains about 300 laws, of which 250 have been preserved. (The others were erased,

presumably to make way for an inscription, by the Elamite conquerors of Babylon.)

We have recovered about 400 decipherable lines of the Lipit-Ishtar code, approximately a third of the complete document. This includes 80 lines of intelligible prologue, 60 lines of epilogue and the texts of 35 laws. About half of our available text is supplied by the four code fragments, the rest by the Lutz and Louvre tablets.

The translation of the Sumerian code has not been completed and the full meaning of many of its passages is still far from clear. But some preliminary comments can already be made on likenesses between the code of Hammurabi and that of Lipit-Ishtar. The structure and general character of the Babylonian paragraphs, as well as the fact that both codes have prologues and epilogues, give us good reason to suspect that the Hammurabi code was framed upon the Lipit-Ishtar pattern. Both royal codifiers cited the same gods, Enlil and An (the heaven god) as their sponsors in the giving of law. Both kings ascribed to the sun god (Utu in Sumerian, Shamash in Babylonian) the ultimate authorship of law and justice. The epilogues of both codes bear similar passages which promise blessing to the man who will respect the legislation, and invoke curses from the gods upon that man who ignores the law, alters the inscription or damages the monument. In sum, the law code of Lipit-Ishtar displays a precedent of form and structure that was more or less closely followed by later lawgivers, including Hammurabi.

The two codes were alike not only in form but in the substance of their laws. To be sure, few instances have been found in which they exactly duplicate each other, but most of the laws in the fragmentary Sumerian code have either close parallels or at least analogues in the Babylonian code. In some cases the two codes are almost identical:

LIPIT-ISHTAR	HAMMURABI
"If a man cut down a tree in [another] man's garden, he shall pay one half mina of silver."	"If a man cut down a tree in [another] man's garden without [the knowledge] of the owner of the garden, he shall pay one half mina of silver."
"If a man rented an ox and destroyed its eye, he shall pay one half the price."	"If a man rented an ox and destroyed its eye, money [equal to] half of its price he shall pay to the owner of the ox."

Where parallels between the two codes exist, there are differences in wording, some slight, some considerable, but the substance of the law usually remains the same. On the other hand, some of Lipit-Ishtar's laws have no counterpart in the Hammurabi code. Two examples are:

"If a man entered the garden of [another] man and was seized there for theft, he shall pay ten shekels of silver."

"If the slave-girl or slave of a man fled into the heart of the city and dwelt in the house of [another] man for one month and it is confirmed, slave for slave shall be given. If he has no slave, he shall pay fifteen shekels of silver."

As to why these laws disappeared in the interval between Lipit-Ishtar and Hammurabi, or why the latter failed to include them in his code, we do not know. The Lipit-Ishtar fragments are still in process of translation. When this is completed, we shall have additional data regarding the differences between Sumerian legal concepts and those of the Babylonians a century and a half later.

FOR nearly half a century the modern world has credited Hammurabi with the institution of codified law. Now, with the discovery of the Sumerian law code, we are able to push the history of codified law back nearly two centuries. No one doubted that laws existed before Hammurabi, for legal clauses had been found in business documents written several centuries before his time. In fact, it is quite likely that earlier codes were even compiled. The importance of the new discovery of the law code of Lipit-Ishtar, however, may well lie in the light it throws upon the social development of lower Mesopotamia in the first half of the second millennium B.C. It gives us further information about Sumerian culture and the role of this people in man's early history. It appears that we should now add the codification of law to the long list of known Sumerian achievements.

There is a passage in the Lipit-Ishtar prologue that further whets our interest. The king, describing a possible mutilator of the code text against whom he invokes the curses of the gods, says, "... he enters the storehouse, cuts down its pedestal, erases its inscription and writes his own name thereon..." This suggests that the Lipit-Ishtar code, like Hammurabi's, was inscribed upon a permanent monument. It is not at all unlikely, therefore, that buried somewhere in southern Mesopotamia, perhaps in the capital city of Isin, the original monument or stele containing the Sumerian code of Lipit-Ishtar lies awaiting the excavator's spade.

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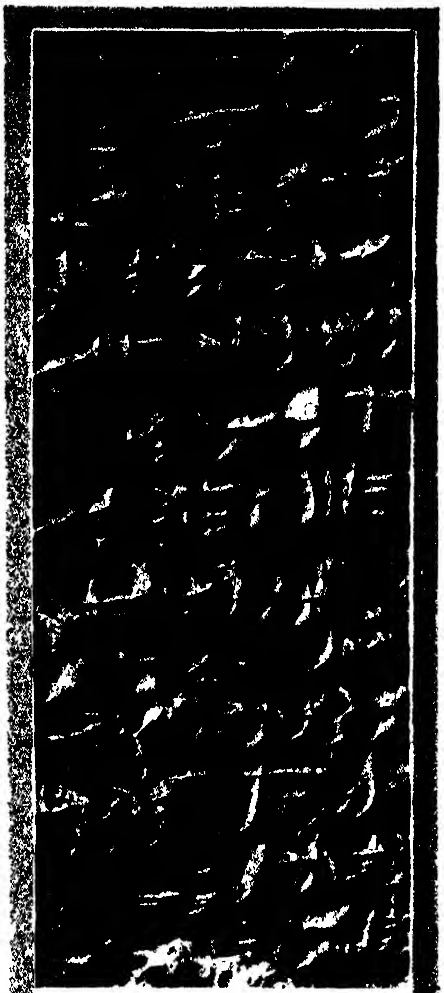
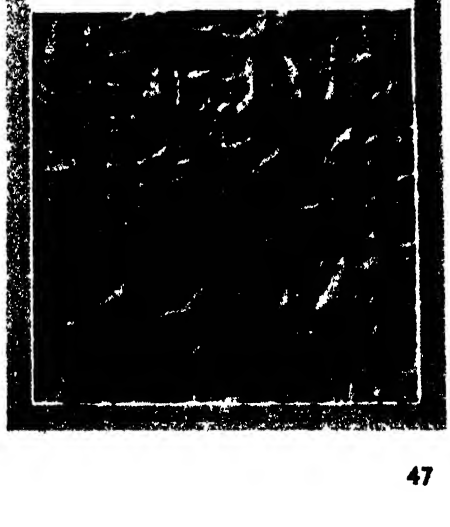
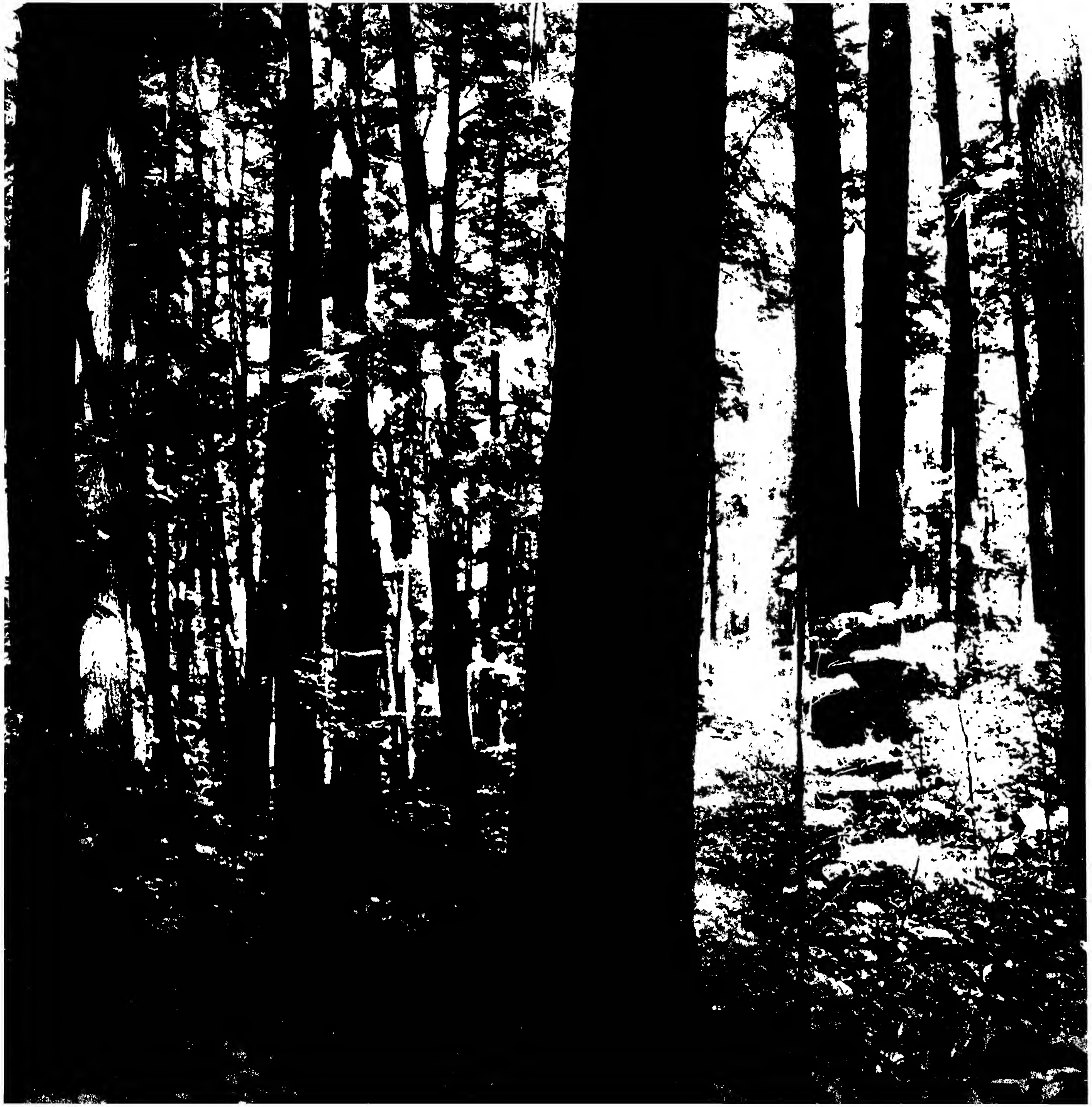
TRANSLATION of the text is matched against the corresponding passages in the original cuneiform.



"If a son-in-law has entered the house of his [prospective] father-in-law and has made his betrothal-gift and afterwards they made him go out [of the house] and gave his wife to his companion; they shall present to him the betrothal-gift which he brought and that wife may not marry his companion."

"If a man rented an ox and damaged its eye, he shall pay one half the price."





WHITE PINE

Once king of the primeval forests from Maine to Minnesota, the noble conifer has exerted a powerful influence in American history

by Donald Culross Peattie

FOR three hundred years, until well after the turn of the present century, White Pine was unrivaled as a timber-producing tree. I will also venture to say that no other tree in the world has had so momentous a career. Certainly no other has played so great a role in the life and history of the American people. Fleets were built to its great stands and railroads bent to them. It created mushroom fortunes, mushroom cities. Earlier, it was a torch in the hands of American liberty. Though now it has fallen dramatically from its high estate to a modest place among the other conifers, its saga is worth recalling.

As a botanist, let me then formally introduce the hero of this saga. You may distinguish it at a glance, almost as far as it can be seen, by its pagoda-like outline and habit of growth. The whorled branches grow in well-separated tiers, like successive platforms of a tower. This structure is as clearly marked in very young specimens as in the oldest, though it is less obvious in dense groves where the older, lower branches have died and the congested crowns are deprived of full development. The persistent smoothness of the smoke-gray or dark slate-colored bark is also a unique trait. No other of our pines has such tardy formation of heavy bark; it finally appears in furrows at the bases of old trees, with rough ridges between the furrows, the ridges built up of purplish scales.

Unlike all our other pines, the White Pine has five needles in a bundle (or sometimes four, in the southern Appalachians). This enables one to recognize at a glance even a detached twig. The needles have a silky feel in the fingers—slim, smooth, soft. They are distinctive with their white bands of stomata which give a slightly glaucous cast to their deep blue-green color.

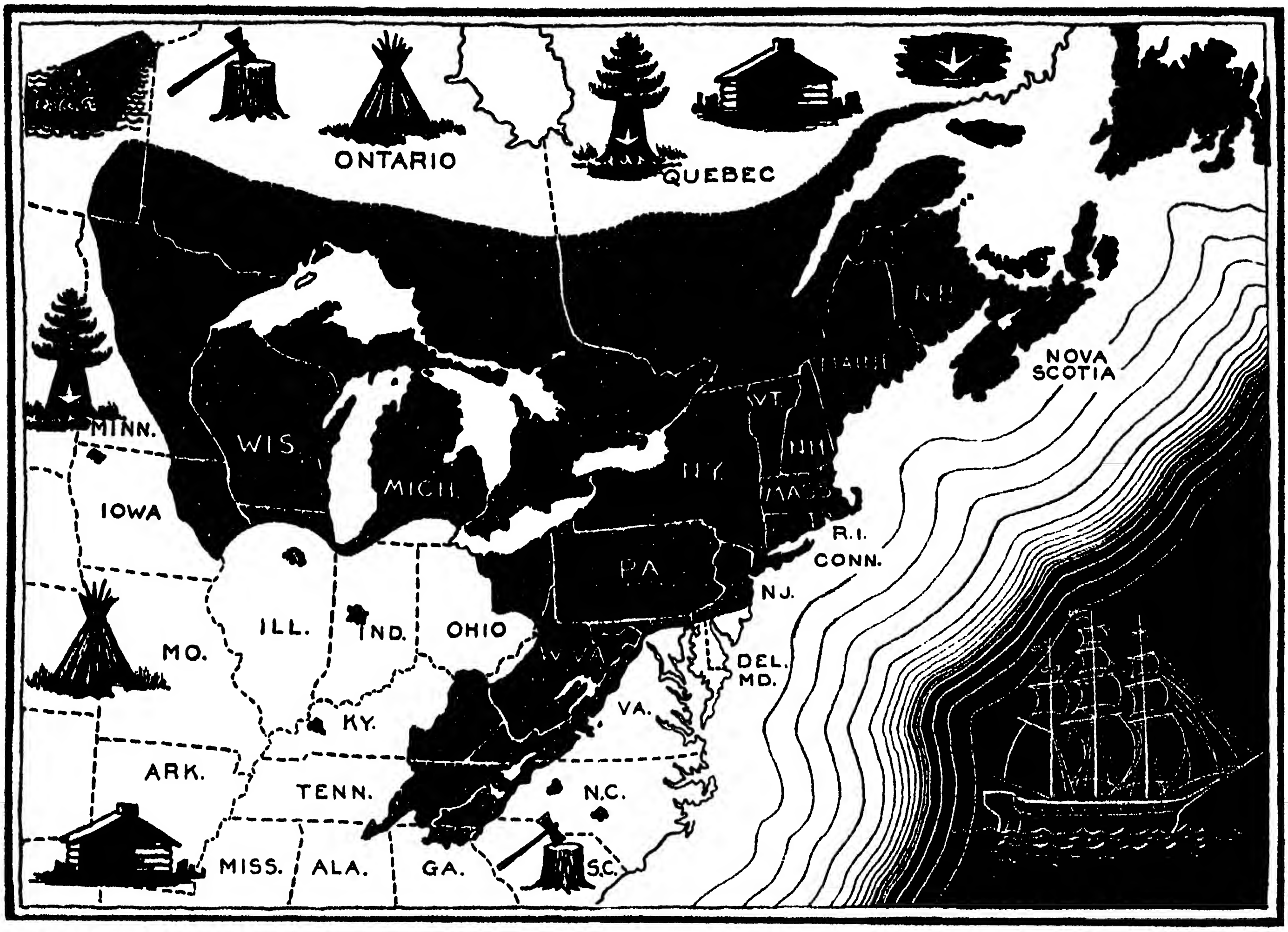
The cones, too, flexible and often sinuous, are unlike all others in our region.

VIRGIN FOREST of White Pine near Warren, Pa., is one of the very few stands that escaped devastation.

They are unique in being pendant on short stalks, in their length and slenderness and in the leathery thinness of their unarmed rounded scales of a pale brown hue. The male catkins, of a bright pale yellow, are clustered at the ends of the twigs. The female conelet appears pinkish, with purplish scales. In one season the conelet ripens into the cone which by October is mature and sheds its seeds on the winds. The foliage, however, persists two years, finally turning yellow and falling when pushed off by the new growth.

The White Pine is a northern species, ranging from Newfoundland to Manitoba and south to Iowa, northern Illinois, central Indiana, eastern Ohio and Pennsylvania. Thence it runs south on the Appalachians to Georgia. In North Carolina, where it is found chiefly on the Blue Ridge, it grows up to an altitude of 3 800 feet. It is at its best above 2,800 feet, in the high cool coves.

In the aboriginal American forest, White Pine was perhaps the most abundant species throughout its range in New England, New York, Pennsylvania, Michigan, Wisconsin, Minnesota and many parts of New Brunswick and Quebec. Over vast areas it formed pure or nearly pure stands, or it had only red pine for an intimate associate, according to the testimony of early "land lookers" (or timber cruisers, as we would say now). The fact that today in those same localities it is intermixed with spruce, balsam, aspen, hemlock, canoe birch, gray pine, and many other North Woods species, only means that the kingdom which White Pine once held as its own has been invaded, since the days of the sawmills, by an influx of trees that once were its humble subjects. Much of Pennsylvania and almost all of New York outside the Adirondacks—so it has been asserted—was one vast White Pine forest. Pioneers used to say that a squirrel could travel a squirrel's lifetime without ever coming down out of the White Pines; and save for the intersection of rivers this may have been but slight hyperbole. When the male flowers bloomed in these illimitable pin-



THE ORIGINAL FOREST of White Pine covered what is now the U.S. from Maine west to Minnesota and south to Georgia and Alabama. Colonial woodsmen worked principally in the forests of southern New England. The great mills of the nineteenth century moved north to Maine and west to Michigan and, finally, to the south.

eries, thousands of miles of forest aisle were swept with the golden smoke of their reckless fertility. Great storms of pollen were swept from the primeval shores far out to sea and to the superstitious sailor seemed to be "raining brimstone" on the deck.

Nor can one easily conceive, from the second growth that is almost all that is left to us, of the toppling height of the virgin White Pines. Trees 150 feet tall astounded the first settlers and explorers; 80 feet or more of the trunk of such a specimen might be free of branches and marvelously straight and thick. On the present site of Dartmouth College a specimen 240 feet in height was measured. This would surpass anything in the eastern United States and would do credit to the Douglas fir of the West, and even the redwood. Similar heights were recorded from Maine, Quebec, New Hampshire and both eastern and western New York in pioneering times. How many others were felled, unmeasured or unrecorded, we cannot know. It was possible for the old land lookers to climb some lofty spruce and from its top sight these mighty groves miles away on the horizon—"clumps," they called them, or "veins of pine" running like sighing rivers through the primeval forest. A branch was thrown down on the ground to point the direction of the groves, and the way was then found through the trackless wilderness by compass.

THE first account in English of this tree appeared in John Josselyn's *Account of Two Voyages to New England* (1674): "The Pine-Tree . . . is a large Tree, very tall, and sometimes two or three fadom about; of the body the English make large Canows of 20 foot long, and two foot and a half over, hollowing of them with an Adds and shaping of the outside like a boat." But White Pine had undoubtedly been carried to Europe by the earliest navigators in Canadian waters. Before the middle of the sixteenth century it was growing at Fontainebleau, and was mentioned then by the French naturalist Belon.

In 1605 Captain George Weymouth of the British Royal Navy sailed his vessels up one of the Maine rivers and, perhaps first of the Englishmen, he got more than a coasting sailor's look at the White Pine. He took away with him specimen logs of mastwood, and seeds or young trees. These were planted at Longleat, estate of Thomas, Viscount Weymouth, second Marquis of Bath, since when the English have called our tree the Weymouth Pine. But it has never proved adaptable to the English climate. Only in its own country was White Pine destined to a great role.

Certainly it was the first gold struck by the New England settlers. The exploitation began immediately and was so intensive that it was soon necessary to pass our first forest conservation laws. Not that anyone then could have envisaged the day when the virgin stands would all be gone, so vast and dense was White Pine's empire; but the wastefulness in the mills began with the first one (built about 1623, at York, Maine) and was never to cease while the virgin timber lasted.

It was not the wood requirements of the puny colonies that threatened this great resource, but the fact that, aside from fish and furs, timber was the only great export of early New England. Within 30 years she was selling her White Pine not only to England but to Portugal, Spain, Africa, the West Indies and ultimately even to densely forested Madagascar.

How one could sell trees to jungle countries can only be explained by recalling that most tropical timbers are heavy and hard; they lack the qualities of lightness and softness in which the

White Pine excels. Weighing only 25 pounds to the cubic foot, dry weight, it is the lightest of all the pines of eastern America, yet in proportion to its weight it is strong. It could be had in solid "sticks" of prodigious lengths for the masts of sailing ships.

Certainly no wood light enough and strong enough for masting was grown in Europe in such lengths. And England, mistress of the seas and forever at war with the other navies of the world, had no mastwood at all. She pieced together her proudest masts out of Riga fir (also Scots pine or *Pinus sylvestris*). But Prussia, Russia, and Sweden held monopolies in it upon which England was dependent, to her own great discomfort. The Danes had only to close the Baltic Sea to cut off her supply entirely. So the arrival of the first White Pine masts created a sensation in the Navy Board. Contracts were let at once to American agents like the Wentworth family of New Hampshire and, with great mast sticks selling at £100 apiece, it is no wonder that the Wentworths grew rich and occupied a position of political power commensurate with their wealth.

IN the meantime other colonists also were growing rich. A great three-cornered trade was set up when, in all-pine ships of their own construction, the New England merchants exported White Pine to the Guinea coast of Africa, shipped on a load of slaves, sold them into bondage in the West Indies, loaded up with sugar and rum, and finally raised sail for Portsmouth, Boston, Newburyport or Salem. Of White Pine boards, and of the wealth that came from this trade, were built the quiet mansions of the seaport cities, the dignified doors, the exquisite fanlights. As tastes grew more sumptuous, exchanges were made direct with the West Indies: light, utilitarian pine was exchanged directly for heavy Santo Domingo mahogany that was made into the most elegant of early American furniture.

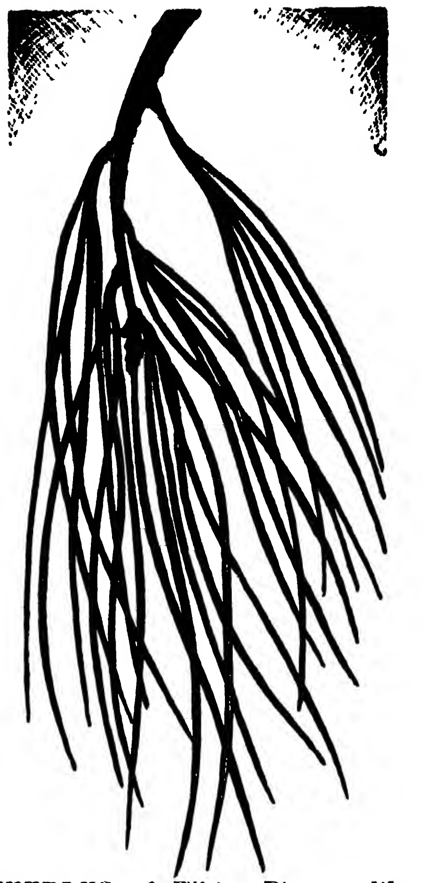
More and more the New England sailing ships came to be decorated by the famous American wood carvers with figureheads of a very special sort of White Pine, so smooth and soft of grain that it could be cut with almost equal ease in any direction. The woodsmen called it "pumpkin pine," contrasting it with the coarser-grained "sapling pine." To the lumberman, as to the wood carver, the distinction was profound. They asserted that sapling pine had more sapwood and that its trunk tapered more from base to crown, while the pumpkin grew on uplands and "held its contour better." Botanists and foresters today believe that the difference was a matter of age; they point out that in our day of second-growth pine, pumpkin is almost unobtainable; it was a product of centuries of undisturbed virgin timber growth.

Few historians mention it, but White Pine was one of the chief economic and psychological factors in the gathering storm of the American Revolution, at least in New Hampshire and Maine. It is also of more than historical interest, for the contest of Great Britain and her American colonies for pine masts engaged forces that are still locked in struggle over the trees of America, however much the values and shibboleths may have changed. These are the forces of conservation and of exploitation, each with its rights and its compulsions.

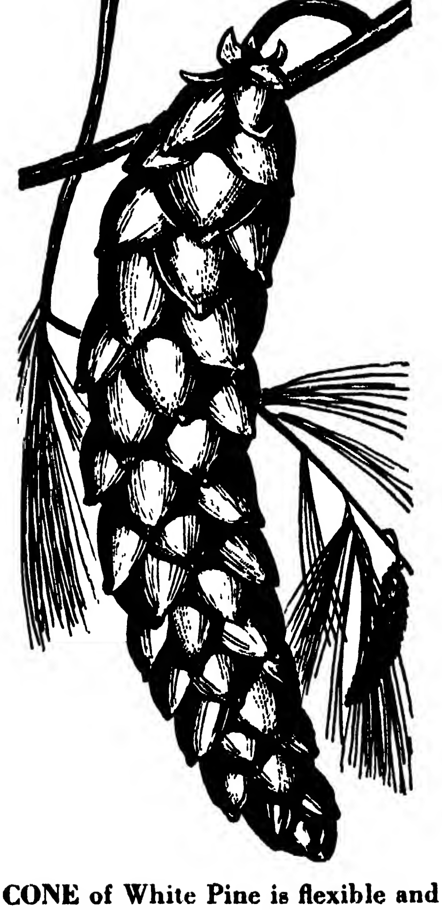
The trouble began in the reign of William and Mary, when by decree those monarchs began to reserve the grandest specimens for the use of the Royal Navy. In her desperate timber shortage, and her endless wars to rule the seas, the mother country naturally looked on aghast when pioneers, advancing far beyond the land grants into the "crown lands" or public domain, chopped down or even burned down the finest trees along with the least, simply to farm the land. It seemed to the British that they were fighting the Empire's battles for the colonists as well as the home country; they could not understand what looked to them like the greed and shortsightedness and refractory spirit of the American pioneers.

To the colonists the same facts looked entirely otherwise. What the Crown called crown lands, reserved to His Britannic Majesty perhaps for sale to London land speculators, appeared to the Americans then as the wilderness was to appear for centuries— as Indian country, theirs for the taking. Unexploited, it was at once an impregnable fortress for cruel savages and the repository of vast wealth desperately needed by a struggling people. The man who could find his way into the primeval forest 50 miles beyond the nearest settlement, cut down gigantic pines, "swamp" them with boom and tackle to the river, ride and pole them down the whirlpools and falls to a secret market in another colony was, whatever else you called him, a man indeed. And as for masts for the wars of the English, the colonists had their own wars with the Indians, and felt capable of winning them if not called on to help fight Spain and Holland and France

So one law, proclamation, or royal instruction after another was passed to restrain the colonists from what on one side of the Atlantic was called timber-stealing and on the other was considered practically the Lord's work. John Wentworth, baron of the New Hampshire pineries, later to become the last royal governor of that colony, was made Inspector General of His Majesty's Woods in America, possessing authority to mark for the Navy Board every great pine in America with a blaze known as the King's Broad Arrow. Tactful, cultivated, genial, he was a conscientious servant of his king. But though he was personally liked by his fellow Americans, the King's Broad Arrow infuriated the pioneer, as the Stamp and Townshend



NEEDLES of White Pine, unlike those of other pine species, hang five, and sometimes four, in a bunch.



CONE of White Pine is flexible and sinuous, hanging from a short stem. Its scales are thin and pale brown.

acts infuriated the merchant, as the tax on tea infuriated the city dweller. Not for this did the woodsman fight his way into the wilderness to make himself a home—only to find that his trees, as he thought of them, had been branded with that hateful symbol of royal privilege. No wonder that he chopped them down, obliterated the blaze, sawed the giants into smaller lengths and floated them down the Connecticut River to New London or some other Sound port for sale and export, perhaps to England's enemies.

The Crown retaliated. In 1761, it instructed the royal governor that in all future land grants a clause was "to be inserted to reserve all white or other Sort of Pine Trees fit for Masts, of the growth of 24 Inches Diameter and upwards at 12 inches from the Earth, to Us our Heirs & Successors, for the Masting of our Royal Navy, and that no such Trees shall be cut —without our Licence on Penalty of the Forfeiture of such Grant, & of the Land so granted reverting to the Crown; & all other Pains and Penalties as are or shall be enjoined or inflicted by any Act or Acts of Parliament passed in the Kingdom of Great Britain."

To make matters worse, a spy system was set up against those who cut trees in violation of these instructions, the spy to receive the land grant of the lawbreaker. In retaliation, the pioneers disguised themselves as Indians and did their cutting at night. A law decreeing that all using such disguises to cut trees should be flogged had no known deterrent effects. American officers would not arrest other Americans for breaking British forest laws made in Britain for the sake of Britons, nor would juries convict them, nor judges impose sentences. British agents drove the loggers from their homes and burned their sawmills, but the loggers had their own laws —"swamp law" they called it—and the territory was not healthy for agents unaccompanied by troops.

WHEN the storm of the Revolution broke, the Americans foresaw that their own White Pines might come back to them as the masts of armed ships, bringing armed men. In 1774, Congress stopped the export of everything, mastwood included, to Britain. In April 1775, after Lexington had been fought, the lumbermen were patriots to a man. A British agent and his mastwrights were captured on the Kennebec River with several masts. When the armed ship *Canceau* sailed into Falmouth, Maine, to protect a Tory rigging and fitting of the mastship *Minerva*, Maine men drove her off. Putting to sea, the men of Machias overtook the armed ship *Margaretta*, boarded and captured her and fitted her out as a privateer. In revenge, the British flattened Falmouth to earth with shot. Down at Portsmouth the patriots seized the great masting pools on Strawberry Bank. The last cargo of American White Pine reached England shortly after Bunker Hill. From then on, the British fought on sea with heavy, jointed masts of Riga fir, while coasting within sight of pines that would have enabled their ships to fight on equal terms.

The first flag of our Revolutionary forces bore for its emblem a White Pine tree. But out of Portsmouth on November 1, 1777, sailed the *Ranger* of Captain John Paul Jones, fitted with three of the tallest White Pine masts that ever went to sea, and from the mainmast fluttered the Stars and Stripes.

The Revolution won, the New Englanders turned to their pineries as the richest natural resource they had. This is not the place to tell the story of White Pine lumbering, the greatest chapter in the history of any nation's forests. There is an extensive literature of the American lumberjack, the old-style lumber baron, the whirlwind exploitation, romanticized in such classics as John S. Springer's *Forest Life and Forest Trees* (1851); bemoaned by Thoreau in our most beautiful forest idyll, *The Maine Woods;* detailed in some 1,200 pages in Defebaugh's unfinished monument, *The History of the Lumber Industry in America*, recounted with gusto for the Rabelaisian details in Stewart Holbrook's *Holy Old Mackinaw*, keened as a wake in his *Burning an Empire;* and exposed in all its grime of ruthless waste, greedy exploitation, bribery, corruption, labor wars and timber thefts in *The Great Forest* by Richard G. Lillard. To sum up a mighty epic in a few lines: it was under the boughs of the White Pine that there evolved the greatest woodsman the world has ever seen, the American lumberjack (though much of the time he was a Finn, Dane, Swede, Norwegian, or Russian by birth). He was an embodiment of the Paul Bunyan legend, a hero of courage and skill amidst toppling giants and river jams, a demon of accelerating destruction. The industry built fortune after fortune, acquired by ruthless exploitation and spent, in many a case, with the highest benevolence. It evolved ever new methods, ever higher efficiency, including efficiency at waste and at lobbying and holding the forces of conservation at bay until the end of the northern pineries was reached.

"RANGER" of John Paul Jones carried the three tallest White Pine masts when she put to sea in 1777.

IN the days of its greatest utility and exploitation, White Pine gained its importance from factors partly environmental, partly inherent in the special properties of its wood. Most of the White Pines grew in a region of heavy snowfall, so the logs could be inexpensively sledded with oxen power to the river. The profusion of rivers made transportation to the mill easy. Add to this the extreme lightness of White Pine that greatly aids it in flotation. Heavy logs like white oak or black locust can be floated with much less success. The great abundance of the forest and the continuity of its stands made it possible to develop a concentrated industry, with mass production and mass marketing and correspondingly cheap rates to the consumer. Then, too, the old-time lumberman was able to operate, in successive localities, on virgin timber. This yielded a much finer grade of wood—longer, smoother, free of defect and knot, and more easily worked than any second growth can ever be.

In the 300 years of its exploitation White Pine, more than any other tree, built this nation, literally and figuratively. It would be impossible here even to list all the uses of White Pine, the most generally useful wood our country has ever possessed. They range from the paneling of fine old colonial interiors to the famed bobsleds of New England, from hobby horses to the annual 72 million board feet of this now precious wood which was still being split into matches in the year 1912. (Western White Pine has now taken over the burden of matchwood.) According to François Michaux, by 1805 half a million American homes were built of White Pine. These were the frame houses that are our most typical form of dwelling, save in great cities, from Maine to Florida and west as far as White Pine was ever shipped on the treeless plains—houses viewed with amazement by foreigners, accepted complacently by natives. No other wood served so well for window sash material; it could be moved at a touch of the hand, yet it did not warp. No other furnished such great clear boards for doors and interior finish. In every sort of millwork White Pine reigned supreme while it lasted. It was the favorite material for heddles of looms, since the weaver had to lift or lower the heddle for every thread that went into the woof. Because it is so light, smooth, easily planed and polished, untold amounts of cheap furniture have been made of it. It takes paint and gilt better than almost any rival.

The number of shingles made of White Pine for the roofs of American homes is beyond calculation. In one 24-year period, Michigan, Wisconsin and Minnesota pro-

duced 85 billion. For two centuries they were hand-rived with a drawing knife. An expert (and he was an artist at his profession) could rive 500 a day and earn a dollar doing it. He professed to know when a given specimen in the forest would rive well, but if he had any doubt he whacked out a big block from the standing tree to test its splitting qualities. If these were unsatisfactory, he simply permitted the tree to bleed its rosin from the cut, leaving thereby a wick that would ignite the tree to its crown in the next forest fire. "The pioneer custom in Kentucky of killing buffaloes for their tongues was little more wasteful than the primitive white pine shingle maker's procedure," say William Hall and Hu Maxwell in a 1911 government bulletin on the uses of commercial woods. "He used only the choicest parts of pine trees. The sapwood, the knots, much of the heart, and practically the whole trunk above the first 20 feet were left in the woods to rot. It was not unusual to sacrifice a 3,000-foot tree to get 1,000 shingles—throwing away about fourteen-fifteenths and using one-fifteenth. The introduction of shingle-making machinery put a stop to that enormous waste, for the saws could make shingles of knots, slabs, tops, cross grains, and all else, from stump to crown. The old-style method of shingle-making died hard, for the shavers opposed the introduction of machines, and declared the ruination of the country would follow so radical a revolution in a widespread industry."

THE famed covered bridges of America were built of White Pine in preference to almost any other wood because of its long-lasting qualities and its lightness in proportion to its strength. Of this wood was built the bridge over the Charles River, connecting Boston and Cambridge, the same on which John Marshall delivered his momentous decision in the Charles River Bridge case, dealing a blow at monopoly. The Delaware River bridge at Trenton (where Washington had crossed through ice floes) and the aqueduct for the State Canal over the Allegheny River at Pittsburgh were White Pine structures. This aqueduct, considered a miracle of its day, was 16 feet wide and 1,020 feet long, with seven spans. It carried one watercourse, and the commerce borne upon it, over another.

"Many of the bridges in the interior of Pennsylvania and West Virginia, by which the old pikes crossed the numerous streams, were built of white pine," say Hall and Maxwell, "and it is said of some of them that no man had lived long enough to witness their building and their failure through decay. Some of these structures were marvels of efficiency. Extra large timbers were unnecessary. Though slight in appearance, they carried every load that came during periods often exceeding half a century. They were roofed—usually with white pine shingles—and were weatherboarded with white pine or yellow poplar, and though painted only once or twice in a generation they stood almost immune from decay."

In each state the White Pine brought sudden wealth; all the great rivers of northeastern America, except the Hudson with its alternating tides, were choked at one time or another with tremendous rafts of logs, each bearing its owner's mark or brand, like cattle going to market. The longest haul was from the pineries of Pennsylvania, 200 miles above Pittsburgh, to New Orleans, 2,000 miles distant by the windings of the streams. One raft that passed Cincinnati covered three acres and contained a million and a half board feet of pine, valued at five dollars a thousand in Pittsburgh, at $10 a thousand in the Creole capital. When the timber was gone, the farmer came in at a temporal distance of about 25 years.

FIGUREHEAD of sailing ships was generally carved from "pumpkin" pine, wood of especially fine grain.

That is to say, the most rosy accounts pictured him as doing so. Actually much of the land could never be profitably farmed. Between the millions of stumps it was acid or rocky; in place of the forest giants of yesterday sprang up the aspen and spruce, the stunted, knotty gray pine, the brambles and the fireweed. Too often the end came in fire and smoke. Forest fires in northern Michigan in the 1890's sent palls of smoke 200 miles down Lake Michigan to Chicago. The Peshtigo fire in Wisconsin killed more people than the great fire of Chicago that began on the same day. The story of what happened to Hinckley, Minn., is an almost unbearable record of human agony. The end was miles of ashes, like a landscape of hell.

By 1900 there was nowhere to turn for virgin White Pine except the southern Appalachians. And certainly there were some dense stands of White Pine in the high coves. Trees 150 feet tall were then known there. At Shady Valley, Va., the yield reached an all-time record, for the South, of 100,000 board feet of White Pine to the acre. So here the industry turned for a last skid to the mills. Not that many of the old-time lumberjacks of Maine or Michigan came this way; they followed the lumber barons and the saws to the "big sticks" of Oregon. In the Appalachians, the industry developed with local resident labor; no great lumber camps ever evolved. Everything that had given lumbering in the North Woods its characteristics was lacking in North Carolina; there was no snow, there were no rivers capable of carrying big logs, no great central mills. Instead, steep inclines, narrow-gauge railroads, migratory mills and stationary labor created a pattern far less picturesque, though not lacking in effectiveness.

The wood also was different. Appalachian White Pine is heavier and coarser than the northern grades, with a somewhat reddish color. In consequence it has never commanded the high price of the best northern pine. The southern "boom" in White Pines lasted from 1900 to 1915.

"No large region of virgin timber remains," said Hall and Maxwell in 1911. "It is not to be expected that this country will ever again see the quality of this lumber it has seen in the past. The large, clear timber, such as once came from the northern pine regions, will never come from there again, because it was sawed or hewed from trees centuries old. It is too much to expect that forests of second growth will be permitted to attain that age or that the owners of trees will wait for them to attain a height of 150 and a diameter of 4 feet."

TODAY the stand of White Pine is in the neighborhood of 14 billion board feet in the U.S. and 8,700 million feet in Canada. Maine, which was one of the first states to lose its paramount position in White Pine production, is once again the leading region in the U.S. This is because the second growth has, after nearly a century, reached maturity.

The glory and tragedy of the White Pine epic had its lessons and its lasting results. The "boom" was, in the nature of historical factors and economic and social pressures, inevitable. The "bust," by dramatizing the situation as in the case of no other American tree roused public opinion to the support of the conservationists, who had fought for years without allies. Though public opinion came too late to save the virgin White Pine, it made itself felt just in time to save a part of the great forests of the western states, to back Theodore Roosevelt and the Forest Service and National Parks in their battle with Congress and the lumber interests.

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SRINIVASA RAMANUJAN

The "profound and invincible originality" of the obscure Hindu mathematician who died in 1920 made possible one of the most prodigious feats in the history of human thought

by James R. Newman

I HAVE here set down, from the scanty materials available, a brief account of the poor Indian boy who became, as one eminent authority has written, "quite the most extraordinary mathematician of our time." Srinivasa Ramanujan died in India of tuberculosis on April 26, 1920, at the age of 33. Except among mathematicians, his name is almost unknown. He was a mathematician's mathematician, and as such, did not attract wide attention outside his field. But his work has left a memorable imprint on mathematical thought.

There are two points which will provide the background for this sketch. The first is that, despite a very limited formal education, Ramanujan was already a brilliant mathematician when he came to England to study in 1914. On the foundation of a volume known as Carr's *Synopsis of Pure Mathematics*, the only book on higher mathematics to which he had access, he had built "an astounding edifice of analytical knowledge and discovery." The nature of Ramanujan's achievement is made clear on examining this one text at his disposal. While a work of real merit and scholarship, it was in fact no more than a synopsis of some 6,000 theorems of algebra, trigonometry, calculus and analytical geometry, with proofs "which are often little more than cross-references." In general the mathematical knowledge contained in Carr's book went no further than the 1860's. Yet in areas that interested him, Ramanujan arrived in England abreast, and often ahead of contemporary mathematical knowledge. Thus in a lone, mighty sweep he had succeeded in recreating in his field, through his own unaided powers, a rich half century of European mathematics. One may doubt that so prodigious a feat had ever before been accomplished in the history of thought.

The second noteworthy point is that Ramanujan was a particular kind of mathematician. He was not as versatile as Karl Friedrich Gauss or Henri Poincaré. He was not a geometer; he cared nothing for mathematical physics, let alone the possible "usefulness" of his mathematical work in other disciplines. Instead, Ramanujan's intuition was most at ease in the bewildering interstices of the number system. Numbers, as will appear, were his friends; in the simplest array of digits he detected wonderful properties and relationships which escaped the notice of even the most gifted mathematicians. The modern theory of numbers is at once one of the richest, most elusive and most difficult branches of mathematics. Some of its principal theorems, while self-evident and childishly simple in statement, defy the most strenuous efforts to prove them. A good example is Goldbach's Theorem, which states that every even number is the sum of two prime numbers. Any fool, as one noted mathematician remarked, might have thought of it; it is altogether obvious and, indeed, no even number has ever been found which does not obey it. Yet no proof which demonstrates its application to *every* even number has ever been adduced. It was in dealing with such problems as this that Ramanujan showed his greatest gifts.

The late G. H. Hardy of Cambridge, a leading mathematician of his time, was professionally and personally closest to Ramanujan during his fruitful five years in England. I have taken from Hardy's well-known obituary of Ramanujan and from his notable course of Ramanujan lectures at Harvard the bulk of the material to be found here; the rest comes from a brief biographical sketch by P. V. Seshu Aiyar and R. Ramachandra Rao to be found in Ramanujan's *Collected Works*. Some of the material is understandable only to the professional mathematician. There is enough, I think, of general interest to justify bringing before the interested layman even this inadequate notice of a true genius' life and work

SRINIVASA Ramanujan Aiyangar, according to his biographer Seshu Aiyar, was a member of a Brahman family in somewhat poor circumstances in the Tanjore district of the Madras presidency. His father was an accountant to a cloth merchant at Kumbakonam, while his mother, a woman of "strong common sense," was the daughter of a Brahman petty official in the Munsiff's (or legal judge's) Court at Erode. For some time after her marriage she had no children, "but her father prayed to the famous goddess Namagiri, in the neighboring town of Namakkal, to bless his daughter with offspring. Shortly afterwards, her eldest child, the mathematician Ramanujan, was born on 22nd December 1887."

He first went to school at five and was transferred before he was seven to the Town High School at Kumbakonam, where he held a scholarship. His extraordinary powers appear to have been recognized almost immediately. He was quiet and meditative and had an extraordinary memory. He delighted in entertaining his friends with theorems and formulae, with the recitation of complete lists of Sanskrit roots and with repeating the values of *pi* and the square root of two to any number of decimal places.

When he was 15 and in the sixth form at school, a friend of his secured for him the loan of Carr's *Synopsis of Pure Mathematics* from the library of the local Government College. Through the new world thus opened to him Ramanujan ranged with delight. It was this book that awakened his genius. He set himself at once to establishing its formulae. As he was without the aid of other books, each solution was for him a piece of original research. He first devised methods for constructing magic squares. Then he branched off to geometry, where he took up the squaring of the circle and went so far as to get a result for the length of the equatorial circumference of the earth which differed from the true length by only a few feet. Finding the scope of geometry limited, he turned his attention to algebra. Ramanujan used to say that the goddess of Namakkal inspired him with the formulae in dreams. It is a remarkable fact that, on rising from bed, he would frequently note down results and verify them, though he was not always

RAMANUJAN, wrote a friend, was "a short uncouth figure . . . with one conspicuous feature—shining eyes . . ."

able to supply a rigorous proof. This pattern repeated itself throughout his life.

He passed his matriculation examination to the Government College at Kumbakonam at 16, and secured the "Junior Subrahmanyam Scholarship." Owing to weakness in English—for he gave no thought to anything but mathematics—he failed in his next examination and lost his scholarship. He then left Kumbakonam, first for Vizagapatam and then for Madras. Here he presented himself for the "First Examination in Arts" in December 1906, but failed and never tried again. For the next few years he continued his independent work in mathematics. In 1909 he was married and it became necessary for him to find some permanent employment. In the course of his search for work he was given a letter of recommendation to a true lover of mathematics, Diwan Bahadur R. Ramachandra Rao, who was then Collector at Nelore, a small town 80 miles north of Madras. Ramachandra Rao had already seen one of the two fat notebooks kept by Ramanujan into which he crammed his wonderful ideas. His first interview with Ramanujan is best described in his own words.

"Several years ago, a nephew of mine perfectly innocent of mathematical knowledge said to me, 'Uncle, I have a visitor who talks of mathematics; I do not understand him; can you see if there is anything in his talk?' And in the plenitude of my mathematical wisdom, I condescended to permit Ramanujan to walk into my presence. A short uncouth figure, stout, unshaved, not overclean, with one conspicuous feature—shining eyes—walked in with a frayed notebook under his arm. He was miserably poor. He had run away from Kumbakonam to get leisure in Madras to pursue his studies. He never craved for any distinction. He wanted leisure; in other words, that simple food should be provided for him without exertion on his part and that he should be allowed to dream on

"He opened his book and began to explain some of his discoveries. I saw quite at once that there was something out of the way; but my knowledge did not permit me to judge whether he talked sense or nonsense. Suspending judgment, I asked him to come over again, and he did. And then he had gauged my ignorance and

(1.1) $1 - \frac{3!}{(1!\,2!)^3}x^2 + \frac{6!}{(2!\,4!)^3}x^4 - \cdots$

$$= \left(1 + \frac{x}{(1!)^3} + \frac{x^2}{(2!)^3} + \cdots\right)\left(1 - \frac{x}{(1!)^3} + \frac{x^2}{(2!)^3} - \cdots\right)$$

(1.2) $1 - 5\left(\frac{1}{2}\right)^3 + 9\left(\frac{1\cdot3}{2\cdot4}\right)^3 - 13\left(\frac{1\cdot3\cdot5}{2\cdot4\cdot6}\right)^3 + \cdots = \frac{2}{\pi}$

(1.3) $1 + 9\left(\frac{1}{4}\right)^4 + 17\left(\frac{1\cdot5}{4\cdot8}\right)^4 + 25\left(\frac{1\cdot5\cdot9}{4\cdot8\cdot12}\right)^4 + \cdots = \frac{2^{3/2}}{\pi^{1/2}[\Gamma(3/4)]^2}$

(1.4) $1 - 5\left(\frac{1}{2}\right)^5 + 9\left(\frac{1\cdot3}{2\cdot4}\right)^5 - 13\left(\frac{1\cdot3\cdot5}{2\cdot4\cdot6}\right)^5 + \cdots = \frac{2}{[\Gamma(3/4)]^4}$

(1.5) $\int_0^\infty \frac{1+\left(\frac{x}{b+1}\right)^2}{\left(1+\frac{x}{a}\right)^2}\,\frac{1+\left(\frac{x}{b+2}\right)^2}{1+\left(\frac{x}{a+1}\right)^2}\cdots dx = \frac{1}{2}\pi^{1/2}\frac{\Gamma(a+\frac12)\Gamma(b+1)\Gamma(b-a+\frac12)}{\Gamma(a)\Gamma(b+\frac12)\Gamma(b-a+1)}$

(1.6) $\int_0^\infty \frac{dx}{(1+x^2)(1+r^2x^2)(1+r^4x^2)\cdots} = \frac{\pi}{2(1+r+r^3+r^6+r^{10}+\cdots)}$

(1.7) If $\alpha\beta = \pi^2$ then

$$\alpha^{-1/4}\left(1+4\alpha\int_0^\infty \frac{xe^{-\alpha x^2}}{e^{2\pi x}-1}dx\right) = \beta^{-1/4}\left(1+4\beta\int_0^\infty \frac{xe^{-\beta x^2}}{e^{2\pi x}-1}dx\right)$$

(1.8) $\int_0^a e^{-x^2}dx = \frac{1}{2}\pi^{1/2} - \frac{e^{-a^2}}{2a+}\,\frac{1}{a+}\,\frac{2}{2a+}\,\frac{3}{a+}\,\frac{4}{2a+}\cdots$

(1.9) $4\int_0^\infty \frac{xe^{-x\sqrt5}}{\cosh x}dx = \frac{1}{1+}\,\frac{1^2}{1+}\,\frac{1^2}{1+}\,\frac{2^2}{1+}\,\frac{2^2}{1+}\,\frac{3^2}{1+}\,\frac{3^2}{1+}\cdots$

(1.10) If $\mu = \frac{x}{1+}\,\frac{x^5}{1+}\,\frac{x^{10}}{1+}\,\frac{x^{15}}{1+}\cdots$ and $\nu = \frac{x^{1/5}}{1+}\,\frac{x}{1+}\,\frac{x^2}{1+}\,\frac{x^3}{1+}\cdots$

then

$$\nu^5 = \mu\,\frac{1-2\mu+4\mu^2-3\mu^3+\mu^4}{1+3\mu+4\mu^2+2\mu^3+\mu^4}$$

(1.11) $\frac{1}{1+}\,\frac{e^{-2\pi}}{1+}\,\frac{e^{-4\pi}}{1+}\cdots = \left\{\sqrt{\frac{5+\sqrt5}{2}} - \frac{\sqrt5+1}{2}\right\}e^{2\pi/5}$

(1.12) $\frac{1}{1+}\,\frac{e^{-2\pi\sqrt5}}{1+}\,\frac{e^{-4\pi\sqrt5}}{1+}\cdots = \left[\frac{\sqrt5}{1+\sqrt[5]{5^{3/4}\left(\frac{\sqrt5-1}{2}\right)^{5/2}-1}} - \frac{\sqrt5+1}{2}\right]e^{2\pi/\sqrt5}$

(1.13) If $F(k) = 1 + \left(\frac{1}{2}\right)^2 k + \left(\frac{1\cdot3}{2\cdot4}\right)^2 k^2 + \cdots$ and $F(1-k) = \sqrt{210}\,F(k)$

then

$$k = (\sqrt2-1)^4(2-\sqrt3)^2(\sqrt7-\sqrt6)^4(8-3\sqrt7)^2(\sqrt{10}-3)^4 \times (4-\sqrt{15})^4(\sqrt{15}-\sqrt{14})^2(6-\sqrt{35})^2$$

THEOREMS of Ramanujan's letter (*here copied from original*) astounded the mathematician Hardy.

showed me some of his simpler results. These transcended existing books and I had no doubt that he was a remarkable man. Then, step by step, he led me to elliptic integrals and hypergeometric series and at last his theory of divergent series not yet announced to the world converted me. I asked him what he wanted. He said he wanted a pittance to live on so that he might pursue his researches."

RAMACHANDRA RAO undertook to pay Ramanujan's expenses for a time. After a while, other attempts to obtain a scholarship having failed and Ramanujan being unwilling to be supported by anyone for any length of time, he accepted a small appointment in the office of the Madras Port Trust.

But he never slackened his work in mathematics. His earliest contribution was published in the *Journal of the Indian Mathematical Society* in 1911, when Ramanujan was 23. His first long article was on "Some Properties of Bernoulli's Numbers" and was published in the same year. In 1912 he contributed two more notes to the same journal and also several questions for solution.

By this time Ramachandra Rao had induced a Mr. Griffith of the Madras Engineering College to take an interest in Ramanujan, and Griffith spoke to Sir Francis Spring, the chairman of the Madras Port Trust, where Ramanujan was employed. From that time on it became easy to secure recognition of his work. Upon the suggestion of Seshu Aiyar and others, Ramanujan began a correspondence with G. H. Hardy, then Fellow of Trinity College, Cambridge. His first letter to Hardy, dated January 16, 1913, which his friends helped him put in English, follows:

"Dear Sir,

"I beg to introduce myself to you as a clerk in the Accounts Department of the Port Trust Office at Madras on a salary of only £20 per annum. I am now about 23 years of age. [*He was actually 25—Ed.*] I have had no University education but I have undergone the ordinary school course. After leaving school I have been employing the spare time at my disposal to work at Mathematics. I have not trodden through the conventional regular course which is followed in a University course, but I am striking out a new path for myself. I have made a special investigation of divergent series in general and the results I get are termed by the local mathematicians as 'startling'....

"I would request you to go through the enclosed papers. Being poor, if you are convinced that there is anything of value I would like to have my theorems published. I have not given the actual investigations nor the expressions that I get but I have indicated the lines on which I proceed. Being inexperienced I would very highly value any advice you give me. Requesting to be excused for the trouble I give you.

I remain, Dear Sir, Yours truly,
S. Ramanujan."

To the letter were attached about 120 theorems, of which the 13 here presented *(see box)* were part of a group selected by Hardy as "fairly representative." Hardy commented on these:

"I should like you to begin by trying to reconstruct the immediate reactions of an ordinary professional mathematician who receives a letter like this from an unknown Hindu clerk.

"The first question was whether I could recognise anything. I had proved things rather like (1.7) myself, and seemed vaguely familiar with (1.8). Actually (1.8) is classical; it is a formula of Laplace first proved properly by Jacobi; and (1.9) occurs in a paper published by Rogers in 1907. I thought that, as an expert in definite integrals, I could probably prove (1.5) and (1.6), and did so, though with a good deal more trouble than I had expected....

"The series formulae (1.1)-(1.4) I found much more intriguing, and it soon became obvious that Ramanujan must possess much more general theorems and was keeping a great deal up his sleeve. The second is a formula of Bauer well known in the theory of Legendre series, but the others are much harder than they look....

"The formulae (1.10)-(1.13) are on a different level and obviously both difficult and deep. An expert in elliptic functions can see at once that (1.13) is derived somehow from the theory of 'complex multiplication,' but (1.10)-(1.12) defeated me completely; I had never seen anything in the least like them before. A single look at them is enough to show that they could only be written down by a mathematician of the highest class. They must be true because, if they were not true, no one would have had the imagination to invent them. Finally . . . the writer must be completely honest, because great mathematicians are commoner than thieves or humbugs of such incredible skill....

"While Ramanujan had numerous brilliant successes, his work on prime numbers and on all the allied problems of the theory was definitely wrong. This may be said to have been his one great failure. And yet I am not sure that, in some ways, his failure was not more wonderful than any of his triumphs. . . ."

Ramanujan's notation of one mathematical term in this area, wrote Hardy, "was first obtained by Landau in 1908. Ramanujan had none of Landau's weapons at his command; he had never seen a French or German book; his knowledge even of English was insufficient to qualify for a degree. It is sufficiently marvellous that he should have even dreamt of problems such as these, problems which

it has taken the finest mathematicians in Europe a hundred years to solve, and of which the solution is incomplete to the present day."

At last, in May of 1913, as the result of the help of many friends, Ramanujan was relieved of his clerical post in the Madras Port Trust and given a special scholarship. Hardy had made efforts from the first to bring Ramanujan to Cambridge. The way seemed to be open, but Ramanujan refused at first to go because of caste prejudice and lack of his mother's consent.

"This consent," wrote Hardy, "was at last got very easily in an unexpected manner. For one morning his mother announced that she had had a dream on the previous night, in which she saw her son seated in a big hall amidst a group of Europeans, and that the goddess Namagiri had commanded her not to stand in the way of her son fulfilling his life's purpose."

When Ramanujan finally came, he had a scholarship from Madras of £250, of which £50 was allotted to the support of his family in India, and an allowance of £60 from Trinity.

"There was one great puzzle," Hardy observes of Ramanujan. "What was to be done in the way of teaching him modern mathematics? The limitations of his knowledge were as startling as its profundity. Here was a man who could work out modular equations, and theorems of complex multiplication, to orders unheard of, whose mastery of continued fractions was, on the formal side at any rate, beyond that of any mathematician in the world, who had found for himself the functional equation of the Zeta-function and the dominant terms of many of the most famous problems in the analytic theory of numbers; and he had never heard of a doubly periodic function or of Cauchy's theorem, and had indeed but the vaguest idea of what a function of a complex variable was. His ideas as to what constituted a mathematical proof were of the most shadowy description. All his results, new or old, right or wrong, had been arrived at by a process of mingled argument, intuition, and induction, of which he was entirely unable to give any coherent account.

"It was impossible to ask such a man to submit to systematic instruction, to try to learn mathematics from the beginning once more. I was afraid too that, if I insisted unduly on matters which Ramanujan found irksome, I might destroy his confidence or break the spell of his inspiration. On the other hand there were things of which it was impossible that he should remain in ignorance. Some of his results were wrong, and in particular those which concerned the distribution of primes, to which he attached the greatest importance. It was impossible to allow him to go through life supposing that all the zeros of the Zeta-function were real. So I had to try to teach him, and in a measure I succeeded, though obviously I learnt from him much more than he learnt from me....

"I should add a word here about Ramanujan's interests outside mathematics. Like his mathematics, they shewed the strangest contrasts. He had very little interest, I should say, in literature as such, or in art, though he could tell good literature from bad. On the other hand, he was a keen philosopher, of what appeared, to followers of the modern Cambridge school, a rather nebulous kind, and an ardent politician, of a pacifist and ultra-radical type. He adhered, with a severity most unusual in Indians resident in England, to the religious observances of his caste; but his religion was a matter of observance and not of intellectual conviction, and I remember well his telling me (much to my surprise) that all religions seemed to him more or less equally true. Alike in literature, philosophy, and mathematics, he had a passion for what was unexpected, strange, and odd; he had quite a small library of books by circle-squarers and other cranks... He was a vegetarian in the strictest sense—this proved a terrible difficulty later when he fell ill - and all the time he was in Cambridge he cooked all his food himself, and never cooked it without first changing into pyjamas....

"It was in the spring of 1917 that Ramanujan first appeared to be unwell. He went to a Nursing Home at Cambridge in the early summer, and was never out of bed for any length of time again. He was in sanatoria at Wells, at Matlock, and in London, and it was not until the autumn of 1918 that he shewed any decided symptom of improvement. He had then resumed active work, stimulated perhaps by his election to the Royal Society and some of his most beautiful theorems were discovered about this time. His election to a Trinity Fellowship was a further encouragement; and each of those famous societies may well congratulate themselves that they recognized his claims before it was too late."

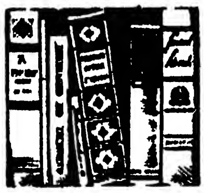
Early in 1919 Ramanujan went home to India, where he died in the following year.

For an evaluation of Ramanujan's method and work in mathematics we must again quote from Hardy. "I have often been asked whether Ramanujan had any special secret; whether his methods differed in kind from those of other mathematicians; whether there was anything really abnormal in his mode of thought. I cannot answer these questions with any confidence or conviction; but I do not believe it. My belief is that all mathematicians think, at bottom, in the same kind of way, and that Ramanujan was no exception. He had, of course, an extraordinary memory. He could remember the idiosyncrasies of numbers in an almost uncanny way. It was Mr. Littlewood (I believe) who remarked that 'every positive integer was one of his personal friends.' I remember once going to see him when he was lying ill at Putney. I had ridden in taxi-cab No. 1729, and remarked that the number seemed to me rather a dull one, and that I hoped it was not an unfavourable omen. 'No,' he replied, 'it is a very interesting number; it is the smallest number expressible as a sum of two cubes in two different ways.' I asked him, naturally, whether he knew the answer to the corresponding problem for fourth powers; and he replied, after a moment's thought, that he could see no obvious example, and thought that the first such number must be very large. His memory, and his powers of calculation, were very unusual, but they could not reasonably he called 'abnormal.' If he had to multiply two large numbers, he multiplied them in the ordinary way; he could do it with unusual rapidity and accuracy, but not more rapidly or more accurately than any mathematician who is naturally quick and has the habit of computation.

"It was his insight into algebraical formulae, transformations of infinite series, and so forth, that was most amazing. On this side most certainly I have never met his equal, and I can compare him only with Euler or Jacobi. He worked, far more than the majority of modern mathematicians, by induction from numerical examples; all of his congruence properties of partitions, for example, were discovered in this way. But with his memory, his patience, and his power of calculation, he combined a power of generalisation, a feeling for form, and a capacity for rapid modification of his hypotheses, that were often really startling, and made him, in his own field, without a rival in his day.

"It is often said that it is much more difficult now for a mathematician to be original than it was in the great days when the foundations of modern analysis were laid; and no doubt in a measure it is true. Opinions may differ as to the importance of Ramanujan's work, the kind of standard by which it should be judged, and the influence which it is likely to have on the mathematics of the future. It has not the simplicity and the inevitableness of the very greatest work; it would be greater if it were less strange. One gift it has which no one can deny—profound and invincible originality. He would probably have been a greater mathematician if he had been caught and tamed a little in his youth; he would have discovered more that was new, and that, no doubt, of greater importance. On the other hand he would have been less of a Ramanujan, and more of a European professor and the loss might have been greater than the gain."

James R. Newman is co-author (with Edward Kasner) of Mathematics and the Imagination.



BOOKS

Posthumous essays by Bronislaw Malinowski

by Abram Kardiner

THE name of the late Bronislaw Malinowski has rightly been associated with the transition of anthropology, once a mere handmaiden of the theory of evolution, to a basic discipline in the study of man. The posthumous collection of five of Malinowski's essays entitled "Magic, Science and Religion" (Beacon Press and Free Press) cuts a swath across the development of his thought. These essays afford an opportunity to appraise Malinowski's place in the social sciences, the current ferment of which he helped set in motion.

The science of man is basically contingent on the degree of insight the social scientist has into the nature of man's mind and emotional life. Such knowledge has been accumulating at a very slow pace indeed. This story of man's growing insight into himself is one still in the making, its greatest chapters yet to come. It is a story in which Bronislaw Malinowski played a significant role.

Malinowski, who died in 1942, was a transitional figure standing squarely astride two important anthropological movements, one impelled by the evolutionary point of view and the other by the psychodynamic. Each of these viewpoints supplied a program specifying the data to be sought and the information to be drawn from them. The evolutionists investigated cultural institutions in the quest for origins and progress in human social organization. The psychodynamic point of view restores man himself as the prime object of investigation; it attempts to describe institutions as implements of adaptation which are predicated on man's basic drives, needs, wishes and anxieties.

The most powerful influence that shook the authority of the early theological assumptions about man and society was Darwin's theory of evolution. This theory gave rise to many new types of investigation, and among its many offspring was the discipline of anthropology. The study of "primitive" man held out high hopes that it would supply valuable information about man's cultural evolution. In a measure—a small one—this hope was satisfied. But when a new area of investigation is the by-product of a parent hypothesis, it is natural that its first efforts will be directed to sustaining its progenitor.

The study of primitive man was therefore biased at its inception. The great names of Edward B. Tylor, James Frazer, Lucien Lévy-Brühl, and Émile Durkheim were associated with these early efforts. They were determined to show cultural evolution by demonstrating that archaic, simple forms of thought and social organization changed into more complex and integrated forms.

The fallacy of this early approach was not only that it colored the conclusions from observed data, but also that it dictated what data should be considered relevant. This is where the theory of cultural evolution did its greatest damage. For these evolutionists were not studying the adaptation of primitive man to his environment. They hopped, skipped and jumped from one culture to another, picked what they wanted from each, and fitted it into their master plan.

This was the scientific atmosphere surrounding Malinowski's introduction to anthropology when he was a student in Cracow. He was determined to follow in the path of Frazer, and would have done so had it not been for an accident. This accident was that during the first World War he was interned by the British in the Trobriand Islands. Here, perforce, he lived for a time with the natives. Thus Malinowski became more than a student of the culture; he acquired almost the status of a participant. From this vantage point Malinowski uncovered new data and developed a new style of interpreting it

HE WAS not alone in his project. William H. R. Rivers of Cambridge and Franz Boas of Columbia University had also charted out new fields. But Malinowski showed that the methods of the evolutionists were faulty. He stated that societies should not be studied as events in a historical scheme but as entities in themselves. Their institutions, he argued, had to be interpreted in the light of the role they played in the adaptation of the community to its natural and human environment Institutions were not merely gratuitous hang-overs from the past, however they were modified. They had an immediate adaptive function; they aided man in his struggle for survival. Malinowski's new school of thought was called *functionalism*.

The essays reprinted in "Magic, Science and Religion" are all illustrative of Malinowski's techniques for making sense from the data of primitive society. He takes up topics such as magic, science, religion, myth, death, language and war and subjects them to a brilliant functional analysis.

Malinowski's field work was remarkable for its precision and meticulousness. In contrast with other ethnographers, he found his primitive men both reason-

able and logical, if one knew their assumptions and frames of reference. Notwithstanding these merits, his account of the Trobrianders does not quite satisfy the specifications for a completely integrated account of a primitive society. His explanations sound very thin today.

The essay in this book which best demonstrates both the strength and weakness of functionalism is entitled *Baloma—The Spirits of the Dead.* Here Malinowski makes a long inventory of the functions of the departed soul after death, and the role it plays among the living Trobrianders. The departed soul has a benevolent and mischievous aspect. No fear is created by either of these in the living. There is, however, great fear of the evil sorceresses who attack the dead. These latter ghoulish figures are not explained anywhere. The functions of the Baloma, or soul, are (among others) to uphold morality and to play some mysterious role in impregnating women The Trobrianders seem to be ignorant of the relation between coitus and impregnation. Malinowski attempts many explanations of this ignorance. The one which he finally accepts, with some reservation, is that, since the natives usually do not become pregnant before marriage in spite of the fact that they begin intercourse as soon as they can, they assume that this particular act cannot be the decisive factor in creating the child after marriage. Accidents do occasionally happen, *i.e.*, children are born out of wedlock. This discrepancy the natives can calmly tolerate without losing their basic belief that impregnation is affected by the Baloma.

One can accept without contest Malinowski's further explanation that the Baloma helps to sustain morality. But one also feels obliged to ask how the natives procure the cooperation of the Baloma, and what is the origin of this particular kind of behavior Why do the Trobrianders not fear the departed dead as men do in other primitive societies? To answer this question one must know something about the role that all fantasy life plays in adaptation, and why fantasies differ as one varies the conditions which make fantasy necessary. These questions Malinowski neither raises nor answers However satisfying Malinowski's explanations may have seemed earlier, today they can rate only as partial answers.

This poverty of specific explanation, in spite of a plausible over-all program, points to a deficiency in Malinowski's technical equipment. He was not prepared for new demands which the science of anthropology was beginning to make. Anthropology had outgrown its original charter. It was now undertaking to understand the entire field of human adaptation under a wide variety of conditions. Such understanding could not be achieved simply by applying a relentless rationalism to the circumstances of a given case. One weakness of Malinowski's method was that it projected upon totally foreign situations the particular brand of rationalism more or less peculiar to Western man.

THIS IS the crucial problem not only of the whole functionalist approach, but of the social sciences in general. Any truly scientific study of man and his institutions requires a technique that takes account of the fact that man's implements of adaptation vary according to the context of conditions in which they develop, and at the same time recognizes the common elements in the motivations and behavior of all men. One must explain, for example, why the fantasy life of the Trobriander is very different from that of the Marquesan. Without a technique that can reduce the fantasy life of both Marquesan and Trobriander to a common denominator, there can be no such explanation.

In Malinowski's working years neither anthropology nor any other social science had such a technique at its disposal. So this deficiency cannot be laid at Malinowski's doorstep. The clues for the development of such a technique had to and did—come from another discipline. The discipline was the psychodynamics originated by Sigmund Freud, who defined the laws which govern the integrative processes in man and the general laws which determine the consequences of the satisfaction or frustration of basic drives. He also described the manner in which the functions of personality are constructed. With these implements the functionalist program could in part, at least, be realized. When these psychodynamic tools are put to work on the raw data of the ethnographer, we can answer some of the questions which Malinowski could not We can get a very complete picture of the general personality traits of the Trobrianders and demonstrate the institutional sources of these traits

Having no such tools, Malinowski got lost in the formal aspects of analyzing and classifying ethnographic data. He lived long enough to see the fruitful application of psychodynamics to the program he had so brilliantly formulated. To this effort he first gave his hearty support, but later, for reasons unknown to the reviewer, his enthusiasm cooled.

The volume here reviewed is probably the last of several posthumous works gathered by Malinowski's literary executors. It is a book everyone interested in the history of the science of man should read. To the reviewer it was the occasion for a fresh tribute to a great scientist whose influence is very much alive in the minds and activities of all those who today are trying to make an accurate and authoritative discipline out of our still fragmentary knowledge of human relations.

Abram Kardiner is co-author (with Ralph Linton) of The Psychological Frontiers of Society.

THE AMATEUR

by Albert G. Ingalls

USUALLY the domed part of an astronomical observatory rotates on top of a fixed cylindrical dome ring, or round wall, but E. K. White of Chapman Camp, British Columbia, has built the two as a single unit which he is easily able to turn by hand on rollers at ground level.

White's North Star Observatory, highest in Canada (3,600 feet elevation), is set on a round concrete slab 18 feet in diameter. To this slab eight five-inch wheels (adapted from V-belt drive pulleys) and their bearings are bolted. An angle iron track is attached to the dome unit and thus rests on the wheels.

The observatory walls are made of quarter-inch, three-ply, resin-bonded fir veneer that is screw-nailed to a base ring made from two layers of overlapping spruce segments and 32 light cedar studs. There is also an upper spruce ring like the first. The dome is made of quarter-inch veneer gores screw-nailed to ribs three inches deep. The ribs, like the rings, are built of overlapped segments.

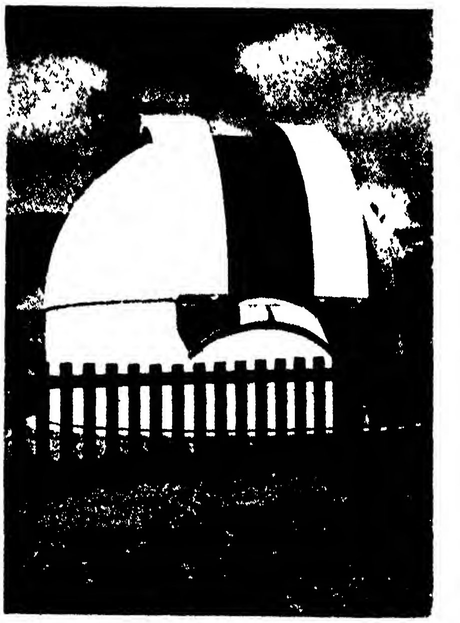
White's double shutters open and close on eight three-inch roller-bearing tackle block sheaves, using Scanlon's method of endless cable described in *Amateur Telescope Making—Advanced*. Unlike most others, White's shutters open a full quarter the diameter of the dome, as recommended by Scanlon, and they extend to the zenith and 10 inches beyond. Prospective observatory builders who discount the importance of a wide slit opening and a large observatory diameter (White's is 15 feet) to accommodate whatever telescope they might want to install in the future, might well consider making their first observatory a poor job. This will effect an ultimate saving when, after enough cussing, they finally tear it down and rebuild it right.

BECAUSE polishing is a far slower method of removing glass than fine grinding, amateur telescope makers have long stressed the importance of avoiding half a lifetime's needless work by bringing their concave mirrors to a truly spherical surface before departing from the grinding stages. In 1935 the recommendation "Get a Sphere Before Beginning to Polish" was inserted in *Amateur Telescope Making* and in an earlier edition (1928) another injunction appeared: "Getting Contact Before Polishing." Amateurs have long tested for sphericity before polishing by the pencil mark test or by the safer method of putting a quick superficial polish on their mirrors with a temporary pitch lap. The latter permits making a Foucault test for checking the sphere.

The Bausch and Lomb Optical Company now furnish details of their recent adoption of this principle and of a production method of accomplishing it with waxed surfaces and test plates which produce Newton's rings.

"The use of wax to test ground glasses started," they state, "in our development laboratory where a check on the flatness of optical surfaces was required. The fine-ground surface is covered with a hard wax. We have used shoe polish, soft red pencils, Johnson's Floor Wax and different types of liquid wax. The only requirement is that the wax be fast-drying and hard.

"After the surface has been coated with a liberal amount of wax it is allowed to dry. Then a hard cloth such as canvas or sheeting is used to wipe up the excess wax and shine the wax that remains between the grindings of the glass. Once one spot of the cloth is used we do not change, for the wax on the cloth tends to fill in any holes not completely filled previously.



The North Star Observatory

"After the piece is completely shined with wax, the test glass is used much the same as on a polished surface. To get a brilliant pattern of interference fringes a good monochromatic light source is needed, since the reflection from the wax is much lower than from polished glass. The pattern seen will be fuzzy but will

ASTRONOMER

give a very good indication of the over-all curvature of the lens or flat. We grind and polish until we have a grind fairly close to the test glass and free from zones, and then we clean the wax from the lens and polish.

"By this test we found we could save many hours of polishing by starting with a zone-free grinding job. The practice has spread to our production department, where we are checking grinding on both planes and weak spheres. This method is good in testing spheres of more than 100 mm radius of curvature but it is difficult to check lenses having a shorter radius."

Amateurs who make several identical mirrors or lenses, as is often the case, may find this use of wax and test plates valuable during fine grinding. It can also be used on single jobs when grinding flats.

One flat which could not be tested against a test plate at any stage was the 120-inch surface made at the California Institute of Technology optical shop some years ago as an accessory for testing the 200-inch mirror at the focus. (Since other tests were applied instead, this, the world's biggest flat, never has been used.) The flat was tested during grinding. Russell W. Porter says, by stretching a piano wire above it, calculating the wire's catenary sag, and measuring the vertical distances from flat to wire. It worked!

Next, after enough fine grinding to give specular reflection at grazing incidence, as shown in the accompanying drawing, a test similar in principle to the one in *Amateur Telescope Making*, page 242, was used. This was Ritchey's test.

Louis J. Rick of 685 North Ridge Road East, Lorain, Ohio, reports a valuable kink he accidentally stumbled upon while fine-grinding his first mirror. "I obtained a very soft drawing pencil, a 6B, with which I drew a broad 3/16-inch stripe across the horizontal diameter of the mirror. Under the Foucault test the stripe was a better reflector than a wet unpolished mirror and showed enough of the horizontal section of the Foucault shadow to permit determining the curve."

PROVIDENCE, in the state whose full and official name is Rhode Island and Providence Plantations, has for years been the center of an active group of amateur telescope makers. In wartime, the Providence group helped to train more than 50 persons in the technique of grinding and polishing glass and then made glass master gauges, optical flats and colored glass filters (thin plane-parallels) for bombsights and sextants. One of this group is Professor C. H. Smiley, head of the De-

partment of Astronomy at Brown University, who as an amateur telescope maker contributes the following practical aid to the amateur "glass pusher."

"Two of the problems which beset the new hand at telescope making are determining whether tool and mirror are making good contact at a given stage of grinding, and estimating the quality of a given fine grind, especially the last one before polishing. If mirror and tool suddenly seize, it probably will be because of poor contact combined with inadequate lubrication. (If you do have such a seizure, be very careful to wash both mirror and tool after separation before going on, because in such an event some glass is almost always removed from one of the disks, usually at an edge, and bad scratches often result.)

"Hours of polishing may be saved by a little extra time and care spent on the last fine grind before polishing. It is proposed here to outline a method by which one can determine whether contact is being made and by which one can measure approximately the quality of a given fine grind.

"If you hold a mirror on your hand almost horizontally at arm's length in front of you, even in the coarser grades of grit you will be able to get a reflection of an electric light down the hall or diagonally across the room. The light ought to be the only bright light in that direction and there should be relatively little light coming in from the sides. An old-fashioned clear glass bulb with the filament showing is perhaps best for this purpose although a good bright frosted bulb will work almost as well. With the mirror well out in front of you, rock it back and forth in such a way that the reflected image of the light moves alternately toward you and away from you. Slowly lower the mirror. As this is done the reflected image grows reddish and dim, eventually is lost. Just before it goes, rock the mirror back and forth very slowly, watching to see whether the image grows dim at one spot more than at another. A dull gray area with poor reflection indicates a zone on the mirror which is not in good contact with the tool; you can judge better on the portion of the mirror away from you than on the nearer part. This is particularly true as the hand drops lower and lower with the finer grades. As a check on your judgment, rock the mirror sidewise a bit and see whether the gray areas seem to come in the same zones as when the image is rocked toward and away from you.

"This test does *not*, however, tell you whether the given grade of abrasive has been used long enough. One still needs a magnifying glass to see whether the pits that remain are essentially of uniform size.

"Now, as the fine grinding proceeds, one finds that the hand may be dropped lower and lower before the reflected image is lost. Also the region in which a

red image is seen increases in size so that there is a generous warning before the image is lost entirely.

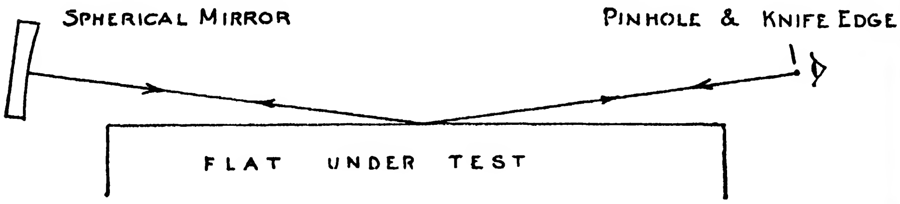
"If now the angle from the light down to the position of the mirror at which the image is lost is measured, the quality of the fine grind can be judged fairly well. A simple and rapid method by which the free hand may be used as a caliper to measure this angle is as follows.

"Suppose the reflected image has finally been lost when the mirror, held in the left hand, is seen in line with a particular crack in the floor or opposite a particular pattern in the carpet. The right arm is now extended in front, full length, parallel with the left. Its fingers and thumb are opened as widely as possible, as in thumbing your nose. The wrist is rotated so that the thumb is straight down, the little finger straight up. With the little finger in line with the light, the point at which the tip of the thumb lines up with the floor is now noted, and the arm is lowered until the little finger on top lines up with the same point. Only one eye is used and the head is, of course, held steady. This spacing off process is repeated on down to a point level with the center of the mirror and the number of 'hands' is counted.

"One then estimates that the mirror is good for about one, three, or so many hands down, as the case may be. Fractional hands may be counted but it is hardly worth while to estimate nearer than a half hand. In general, the number of hands measured by one person will agree fairly well with the number found by another person of radically different dimensions.

"Our experience has been that a good grind with 500 Carbo or Aloxite should show about three hands down; 303 emery will give four hands, and 303½ emery should give five and a half or six hands, but the average beginner usually wants to quit at five hands down and start polishing. In terms of time and energy this is a very expensive procedure. He should go back to 303½ for a final wet, adding only a little water from time to time and slowly working out the abrasive. The pressure of the hands should be lessened in the later stages of fine grinding until, in this final step, it should be just the weight of the mirror applying the pressure. If you hold your ear down close to the mirror as you move it back and forth in this final stage you will hear a faint swish reminiscent of silk. This 'repeated dilution of the final wet' resembles the 'Ferson technique' of drying up the final wets, adding only a very little water, and working the emery out to the finest possible state. The latter is described in detail by Ferson in *Amateur Telescope Making—Advanced.* [In printings subsequent to June 1944.—*Ed.*]

"When you get down to four or five hands you should take care that no oil or grease is applied to the mirror as you wipe the last bit of moisture from it. Only a small amount of grease is enough to mislead one seriously as to the quality of the fine grind. Just rubbing the hand over a mirror several times appears to provide the grease which misleads.



The testing of the biggest flat in the world

"Although this note is not meant to cover polishing, one of the commonest troubles encountered in polishing is the 'Mexican Hat.' Under the Foucault test, with the mirror in an intermediate position, there appears to be a turned-up edge (the brim of the hat) and a hill in the middle (the crown of the hat). As long as the hat is a fairly flat one, in comparison with its diameter, this is not a serious matter. Care taken in pressing the mirror on the lap each time before starting polishing, and in using a very short stroke, will usually prevent the appearance of a Mexican Hat and many times will remove one after it has appeared. It seems likely that the hat is a result of the natural curvature of a pitch lap near its edges due to surface tension."

EVERY year in their Science Talent Search the Science Clubs of America boil down several thousands of the nation's keenest high school seniors to award the Westinghouse Science Scholarships. A part of the boiling-down process is a written report on a science project selected by the candidate. Of the 40 finalists in the Science Talent Search this year, five chose telescope making as their project, roughly the same percentage as in the six previous annual talent searches. An examination of some of the essays which were written by the finalists reveals that the best of the contestants have mature, adult minds—keen and scientifically sophisticated.

Albert G. Ingalls is author of Amateur Telescope Making *and* Amateur Telescope Making—Advanced.

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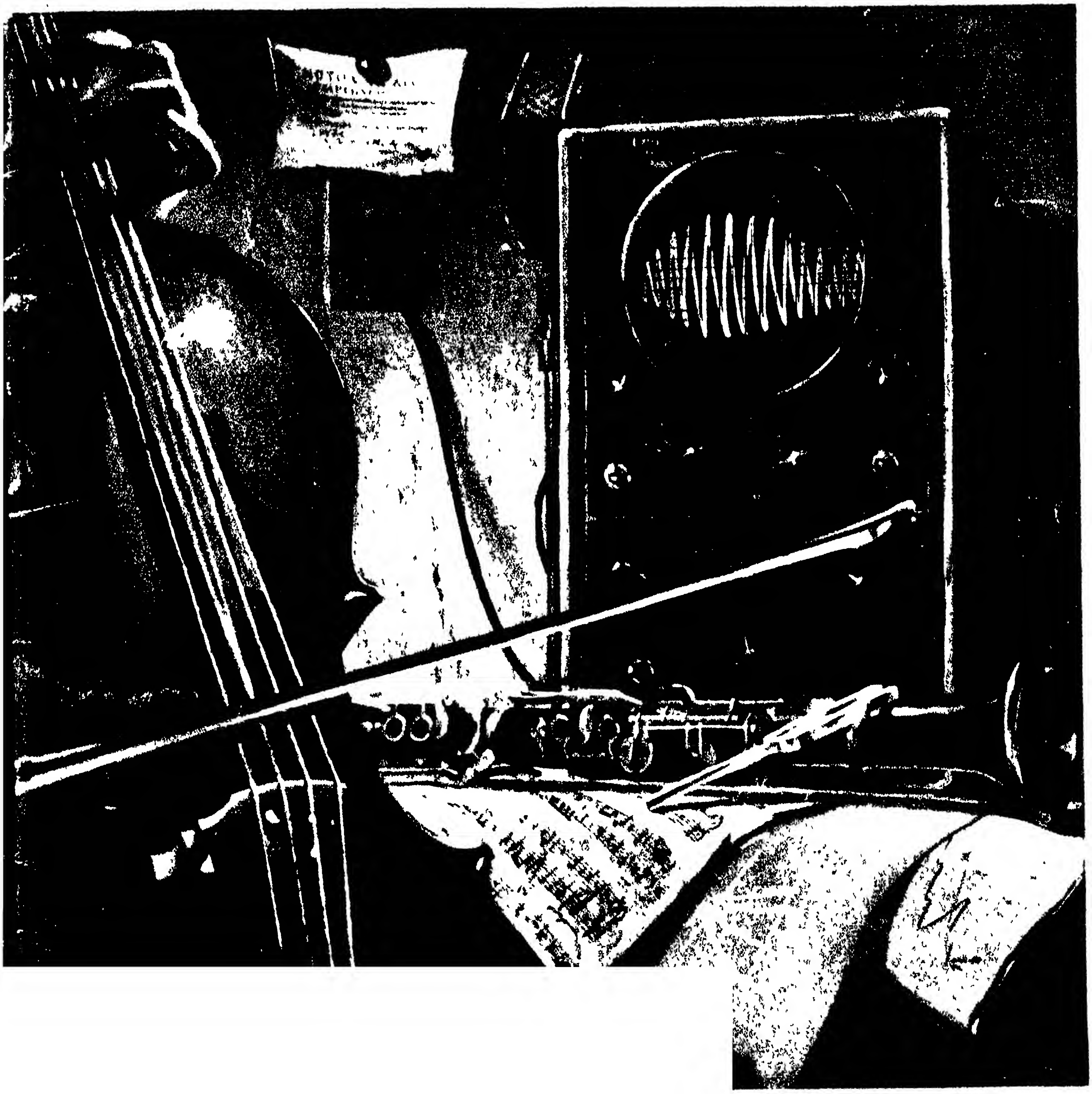

FIFTY CENTS

July 1948

LETTERS

Sirs:

Concerning "social physics"—and your May article of the same name—I should like to register an emphatic protest at the inclusion of this kind of balderdash in your otherwise commendably restyled magazine.

"Now," wrote your associate professor of astronomical physics, "let us apply these equations to populations. In the place of mass or charge we substitute 'population density.' This term is actually derived from the physical concept of surface density; the analogous unit in electrostatics would be the amount of surface charge per unit area of the charged body." And again: "The gas analogy, or some equivalent concept, is necessary to explain the resistance of human beings to social gravitation . . . Were it not for the expansive force of the human gas, representing the need of individuals for elbowroom, the center-seeking force of gravitation would eventually pile everyone up at one place."

Frankly, social scientists themselves are not without occasional foibles, fancies, strange preoccupations and conceits, but in a number of years of close attention to the theories and researches of persons active in this field I have encountered nothing quite so weird as the notions drummed up by your contributor, the associate professor of astronomical physics.

I am in no sense objecting to his interest in the mathematical description of social behavior. Wherever uniformities in social behavior can be found to exist, symbolically described, and their interrelations generalized, let us by all means do so. That is the end toward which all of our sciences should properly be working. But if there is one most effective way of damning all hope for the continued progress of social science toward this objective, it would almost certainly lie in beginning with the concepts of physical science, then observing social behavior, then jam-packing our findings into the usually quite irrelevant concepts with which we have begun. At best, such a procedure might afford a harmless and no doubt intriguing pastime for occasional professors of astronomical physics. At worst—which is to say, if taken seriously—the same procedure represents a gross and unpardonable failure to approach the data of social behavior at their own level and in the terms which they themselves suggest.

May I offer two suggestions?

First, I would be happy at any time to test my skill at the "social physics" game by devising a new approach to the data of physical science, one which would make use of many concepts that physical scientists have unaccountably ignored, such as "minority groups," "frustration," "aggression," "in-group," "folkways," and so on. Surely the proffer of a physics of sociology deserves a sociology of physics in return, if only to show that practitioners of social science are equally capable of benevolence and versatility.

Or, somewhat more pointedly, it might be suggested that the editors of *Scientific American*, when preparing future articles on social science topics, first secure the views of social scientists concerning the usefulness and validity of material to be treated.

It would be sheer ingratitude not to add that, apart from the perilous flight of fancy in question, the May *Scientific American* was unusually pleasant reading, attractive and interesting.

WALTER H EATON

Director
Research Associates of Chicago
Chicago, Ill.

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Sirs:

Professor John Q. Stewart, in his article "Concerning Social Physics" in your May issue, does not, alas, carry us into the post-Keplerian stage of social thinking. Rather he transports us to a pre-Heraclitean era where we are asked to believe in unexamined generalities and mysterious pseudo-forces like "population potential" and the "human gas."

I do not think that Professor Stewart's position is defensible even on the facts. The particular area of high population potential which he discusses is the Illinois, Indiana, Southern Michigan, Ohio, Pennsylvania, New York, New Jersey, Connecticut and Massachusetts group of states. While it is true that this is an area exercising relatively strong influence in the country as a whole it is also characterized not only by relatively high population density but also by the following: high purchasing power, large coal deposits, cheap water transport, heavy and early development of rail transport. It also contains much of the best farmland in the country. Thus, what is at issue here is not a force exercised by virtue of population density (or "potential") but a force exercised by virtue of a complex of interrelated factors. It ought to be borne in mind also, it seems to me, that were population potential a deciding factor in the influence of a region on its environment, then the influence of India and China in the world would be overwhelming as compared to our own. But we know that population by itself—without industry—is nothing in the world today.

A further problem is raised by Professor Stewart's concept of the "human gas." It is true that populations have always tended to move from rural to urban areas, *i.e.*, from areas of relatively sparse population to areas of relatively denser population. But this is not due to the pseudo-scientific force invented by Professor Stewart and called "demographic gravitation." In the history of our country, and of much of the world, the rural population has migrated to cities in search of a higher standard of living, or in some cases, as an escape somehow, as in Latin America, from the intolerable misery of the countryside. Thus, to invoke such a "force" as "demographic gravitation" to explain complex emotional phenomena obscures rather than illuminates the issues.

But the wanderings of an occasional astronomical physicist into the uncharted (for him) interstellar space of society, are really not as important as the implications of his kind of *thinking*. Mechanistic treatment of social phenomena distracts attention from the real problems of social living. The consideration of persons as particles paves the way for those who would treat them as assembly-line items to be organized and handled as any political party wishes. This problem of the relationship between the physicist and society is of crucial importance because so many physicists have been swept into pivotal social positions on the wave of popularity that—ironically enough—followed on the most catastrophic demonstration of the power of the physical sciences in history. Personally, I think that Professor Stewart's kind of thinking is the backdoor to tyranny.

JULES HENRY

Associate Professor of Anthropology
Chairman, Basic Social Science Program
Washington University
St. Louis, Mo.

●

Sirs:

I have been trying to read the May issue of your magazine.

Man, oh man. You have ruined the finest

shop and hobby magazine in the world. Gone high-brow. Filled it with a bunch of uninteresting junk which anyone can find in any well ordered library—assuming he wants to find it.

Most of the subscribers of the old *Scientific American* can meet these qualifications. But even the college graduate is sometimes glad to know that a eutectic bismuth alloy can now be had for making cheap molds for short runs of plastic parts or to learn, from the column written by Mr. Albert G. Ingalls, what abrasive to use for polishing glass or metals. And thousands of other helpful hints which can be used from day to day.

I note that Mr. Ingalls is being kept on as one of the editors of your new magazine. I'll give odds that he is the only one of the new editors who has ever cleaned his hands on a piece of dirty waste. I'll gamble also that, with his age and experience, you will find Mr. Ingalls is dry behind the ears. As long as my subscription lasts I shall welcome and find interest in Mr. Ingalls' column.

Gone from your subscription lists will soon be your present subscribers and gone from the greasy work benches throughout the world will be the magazine of a thousand helpful hints which we liked so much, and which your new magazine can never replace.

Gone also is the idea which has endured for over a hundred years, that a magazine can be helpful to people of *all* walks of life. Comes now the idea that only those who qualify as "intelligent laymen"—"at, say, a college level"—can understand science. Tsk, tsk. What a crime—what a shame. And what a conceit.

The old friends of the old *Scientific American* may not write many letters to you but they will have the same feeling as do I, which can be best expressed in the language of the prize ring, "We wuz robbed"

PHILIP E. DAMON

Ames, Iowa

●

Sirs:

The new *Scientific American* is perfectly splendid! It is just what a scientific magazine ought to be! And I (and legions like me, I am sure) am delighted that the historic periodical is returning to its birthright.

May I humbly beg that you will keep it from again becoming too metallurgical, commercial? I know you will safeguard it. My father drew his chief interest in life from the pages of the older, broader form it had; and to which it is now so happily returning. We all thank you!

LEON A. HAUSMAN

Department of Zoology
New Jersey College for Women
New Brunswick, N. J.

50 AND 100 YEARS AGO

JULY 1898. "On June 6, 1898, the discovery of yet another element was announced, in a communication made by Prof. Ramsay, of London, to the Academy of Sciences, of Paris. This new element is the gas krypton, and makes a fifth constituent of the atmosphere; it is, however, present in very minute quantities, viz., one part in ten thousand of its volume. Krypton belongs not to the argon, but the helium group; its density is greater than that of nitrogen, being, according to the corrected measurement, 22.47."

"The present war has served as a great upsetter of theories. Seagoing Spanish torpedo boat destroyers, that were to have wiped out our mosquito fleet and then proceeded to sink our battleships in detail, have proved helpless against our unarmored cruisers, and Spanish forts that were to have crumbled to dust at the attack of our 13-inch shells have persisted in holding up their heads with a stubborn endurance of which these medieval traps of stone and mortar were theoretically quite incapable. We find that some pet theories will have to be renounced, if the earlier operations of the present struggle are a sure indication. Conspicuous among them is the oft-repeated statement that warfare has become such an exact science as to leave little room for the exercise of mere courage and daring."

"The auxiliary steam yacht 'Windward' left New York on July 2, for Sydney, Cape Breton, in command of Capt. John Bartlett, who has made four trips to the Arctic regions. Mr. Peary and other members of his party will join the 'Windward' at Sydney. From Sydney the yacht will go to Cape York, Greenland, where she will take aboard a party of 60 Esquimaux with their sledges and dogs."

"Prof. Koch has announced the results of his investigations on the plague. He declared that the view entertained some two years ago that the plague no longer threatened mankind must be abandoned, for there are now no less than four plague centers, the last of which Prof. Koch discovered in the Hinterland of German West Africa."

"Further evidence of the existence of man before the glacial period in England has come to light. In his address before the Biological Society, of London, Dr. Hicks states that the evidence which has been obtained from bone-bearing caverns in the glaciated regions of England shows conclusively that the remains of the extinct mammalia found in them must have been introduced before any of the glacial deposits now in or upon them could have been laid down. From caverns, he says, in glaciated areas in North and South Wales, where paleolithic implements have been found in association with remains of extinct mammals, facts have been obtained which make it certain that the implements were those of man living at the same period as the extinct animals in those periods, and therefore of pre-glacial age."

"Our readers are already familiar with the harrowing details of the loss of the 'Bourgogne', with 560 lives, in the North Atlantic. Contrasted with the detestable cowardice and villainy of the crew, it is a mournful gratification to know that the officers did their duty to the last and to a man perished with the ship. The awful suddenness with which the ship went down as the result of the failure of her watertight compartments will shake the confidence of the public, already rudely strained, in the system of watertight bulkheads as a means of keeping an injured vessel afloat."

"The director of that stupendous enterprise, the Trans-Siberian Railway, announces that the whole line will be opened to traffic in 1904. It will then be possible for the 'globe trotter' to circle the earth in thirty days or less."

JULY 1848. "At the Isthmus of Tehuantepec one river named Coatzocales, flows into the Gulf, and the river Chicapa flows into the Pacific. Both these rivers originate on an elevated table land near the centre of the isthmus, about 656 feet above the ocean, and the length of the route would be 200 miles, therefore we need never expect a canal to be built there; but the Isthmus of Panama can be cut and built into a splendid canal at an expense of no consequence at all, as the distance from sea to sea is only about 40 miles, and the country is traversed for nearly the whole width by the great river of Chagres and its tributaries."

"It has been officially stated that there are 3,719,000 persons engaged in agricultural pursuits in the United States; in manufacturing, 781,800; in commerce, 119,600; in learned professions, 65,200; in ocean navigation 55,000 and in internal navigation no less than 33,000."

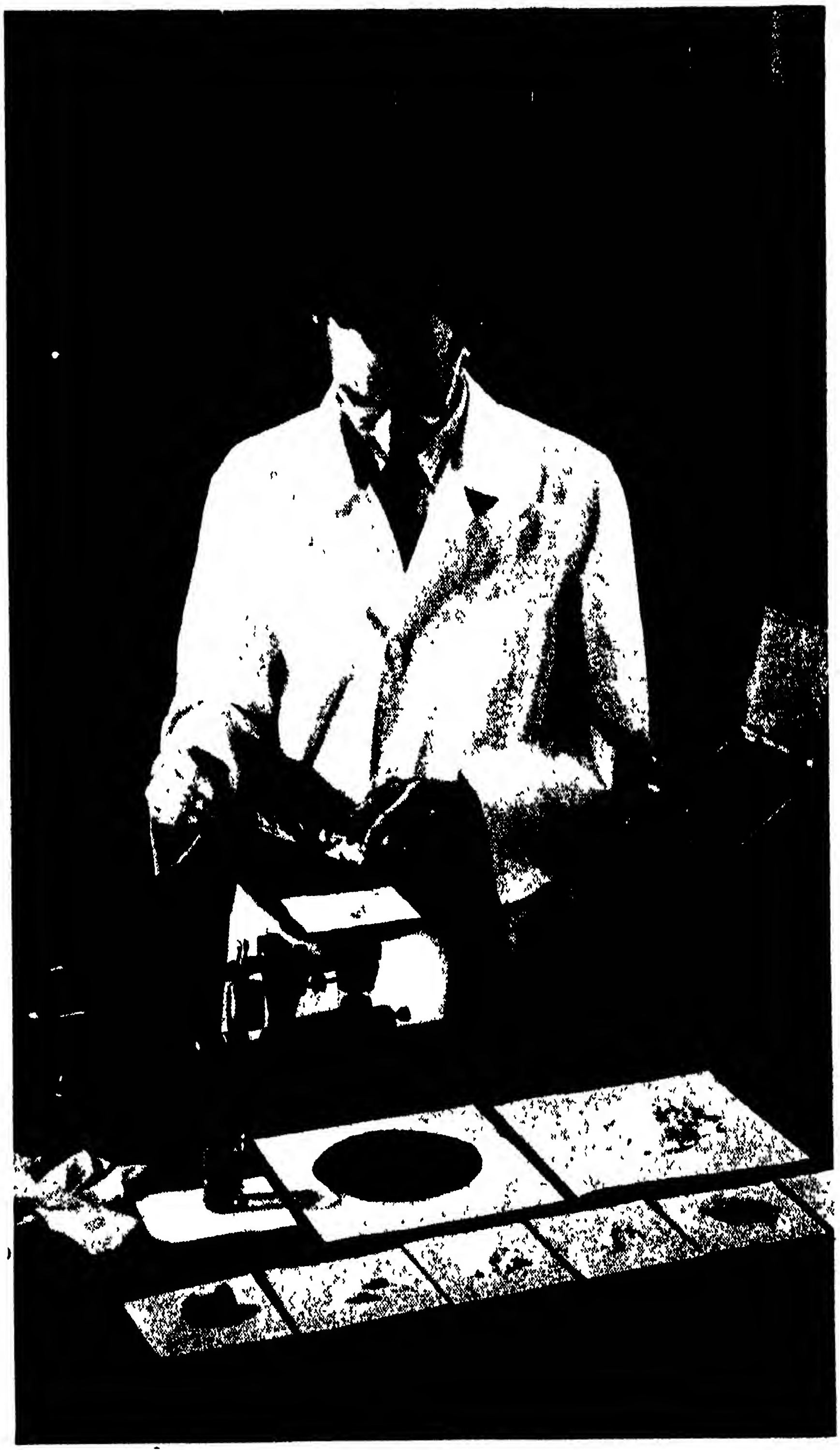
"The Italians have beaten the Austrians in a severe engagement—one King knocking down another. There is a prospect of peace between Denmark and Prussia. The crops in England look well. France is still disquieted and it is reported that Prince de Joinville has been taken prisoner incog. in Paris. France will it is supposed, yet relapse into the arms of monarchy. With all the noise lately made in Europe, there is but one crowned head the less—only one vacant throne. There is every appearance of Spain and England coming to blows. This is a prelude to the conquest of Cuba—let us see if this be so, or not."

"The hanging bridge of Kerentrech is spoken of as one of the most remarkable objects of modern art in France. It is thrown over the little river Scorfi, at the place where it crosses the road from Lorient to Paris, at the bottom of the beautiful avenue of Chazelles. The bridge differs from all those which have been heretofore built, inasmuch as its power of suspension rests entirely on cables of iron wire."

"He who created heaven and earth,
And gave the rolling thunder birth,
Who hold'st the ocean in his hand,
Whose waves are stayed at his command,
Who made the gorgeous sun to gild
The humblest cot that man can build,
Who strewed the earth with lovely flowers,
And gave to man gigantic powers,
Hath kindly unto Morse revealed
What heretofore had been concealed.
He doth the rapid lightning tame—
A Telegraph he calls its name—
And with a single vivid flash,
A dot—a space—a line—a dash—
Can send around the earth the news,
Or stop it, just as he may choose,
What a mysterious mighty power!
No noise is heard—no cloud doth lower,
And yet the lightning wings its way,
And tells whate'er we have to say."

"It is stated that Daniel Webster speaks at the rate of from eighty to one hundred and ten words per minute; Gerrit Smith, from seventy to ninety; Dr. Tyng, from one hundred and twenty to one hundred and forty; Mr. Botts, from one hundred to one hundred and twenty; Mr. Clay from one hundred and thirty to one hundred and sixty; Mr. Choate and Mr. Calhoun, from one hundred and sixty to two hundred."

RUBBER RECIPE



Rubber compounds to the tune of some 35 million pounds a year go into Bell System plant. Each compound must meet many requirements for resistance to humidity, oxygen, ozone, light and abrasion. The right properties depend on skillful selection and compounding of ingredients; this is one of the jobs of Bell Laboratories.

Sulphur, one essential ingredient of rubber, can also be corrosive. That seemed to rule out rubber on telephone cords. But Bell chemists found that if they held sulphur to the bare minimum, corrosion ceased. Now your handset cord has long life, is less susceptible to moisture as, for example, from a wet umbrella.

Connecting your home to the telephone wire on the street is a "drop" — one hundred feet or more of rubber-insulated wire. Once this wire was protected from ozone, light and abrasion by an impregnated cotton braid; but water leached the impregnant, and the braid rotted. Bell chemists tested scores of synthetics, and selected neoprene as an exterior covering with many times the life of braid.

Rubber is only one of many types of insulation developed by the Laboratories for the Bell System; insulation is only one of the Laboratories' problems in providing a quick, economical path for your voice.

BELL TELEPHONE LABORATORIES

EXPLORING AND INVENTING, DEVISING AND PERFECTING FOR CONTINUED IMPROVEMENTS AND ECONOMIES IN TELEPHONE SERVICE.

THE COVER

The cover painting for this issue illustrates one of the methods in the physical study of music, the place of which is discussed in the article "Physics and Music" on page 32. At the left a cello sounds a note which is recorded on the oscilloscope at right.

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SCIENTIFIC AMERICAN

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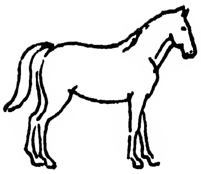
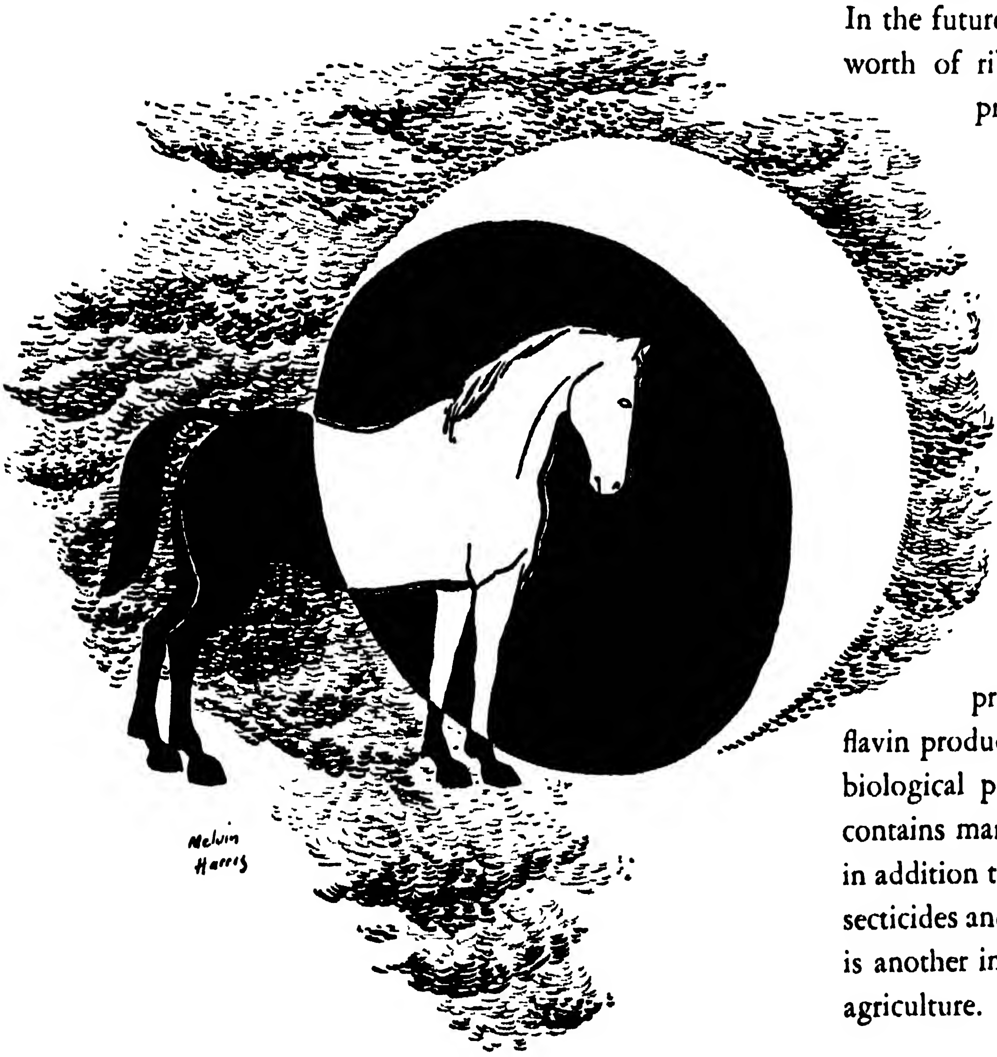


It's an old superstition that men go mad in the moonlight, but did you ever hear of moonbeams blinding a horse? In 400 A.D., the Romans gave the name "moon blindness" to an equine eye disease because they believed it was caused by lunar changes.

Recent veterinary studies made by the Army show that moon blindness is a vitamin deficiency. Responsible for more blindness in horses and mules than all other causes combined, it occurs when diet lacks riboflavin.

the horse that went blind in the moonlight...



Moon blindness now costs American horsemen more than $17,000,000 a year. In the future, breeders will add a penny's worth of riboflavin to each feedbag to prevent this destructive disease.

Riboflavin is essential to the health of poultry and livestock. Without it, chickens develop curled-toe paralysis, lay eggs that will not hatch, and lack vigor. Riboflavin promotes healthy growth and sound development in young cattle, pigs, dogs, and fur-bearing animals.

For years feed men have preferred B·Y-21, a natural riboflavin product made by an exclusive CSC biological process. This natural product contains many valuable nutritive elements in addition to riboflavin. Like the new insecticides and veterinary penicillin, B·Y-21 is another important CSC contribution to agriculture.

COMMERCIAL SOLVENTS CORPORATION CSC 17 EAST 42ND STREET, NEW YORK 17, N. Y.

SCIENTIFIC AMERICAN

JULY 1948 VOL. 179, NO. 1

RECOVERY OF EUROPE

A UN survey presents the balance sheet: Despite its remarkable postwar comeback, the Continent must yet find a way to reduce its $7.5 billion import deficit

The "E. C. E. Report," here summarized, is designed as a guide to the postwar recovery of Europe. Prepared by the Research and Planning Division of the Economic Commission for Europe under directive of the Economic and Social Council of the United Nations, it was published at Geneva in April under the title A Survey of the Economic Situation and Prospects of Europe. *The Commission's executive secretary is Gunnar Myrdal, noted Swedish economist. The U. S. and all European members of the UN are full members of the Commission. Practically all European countries are participating, however, in the work of its technical committees, and all of them, with the exception of Spain and Portugal, attended the recent meeting of the full Commission held in Geneva. During the first year of its operations, the Commission's numerous technical committees have succeeded in effecting improvements in a number of critical areas of the European economy, even though its powers, like those of all other special UN agencies, are limited to recommendations. The Commission greatly assisted railway transportation, for example, by recommending an improved system of freight car exchange which promoted traffic across international boundaries. As another example, it increased European steel production by 1.5 million tons in the current year through allocation of coke and coal among the European countries.*

The present Report was a working document of the recent meeting of the Commission. This summary, prepared by the editors of SCIENTIFIC AMERICAN, *sets forth the essential findings of the 200-page Report. It should serve as a valuable source of information for U. S. citizens and help them to understand the economic situation of Europe, in which their country has assumed such heavy responsibility.*

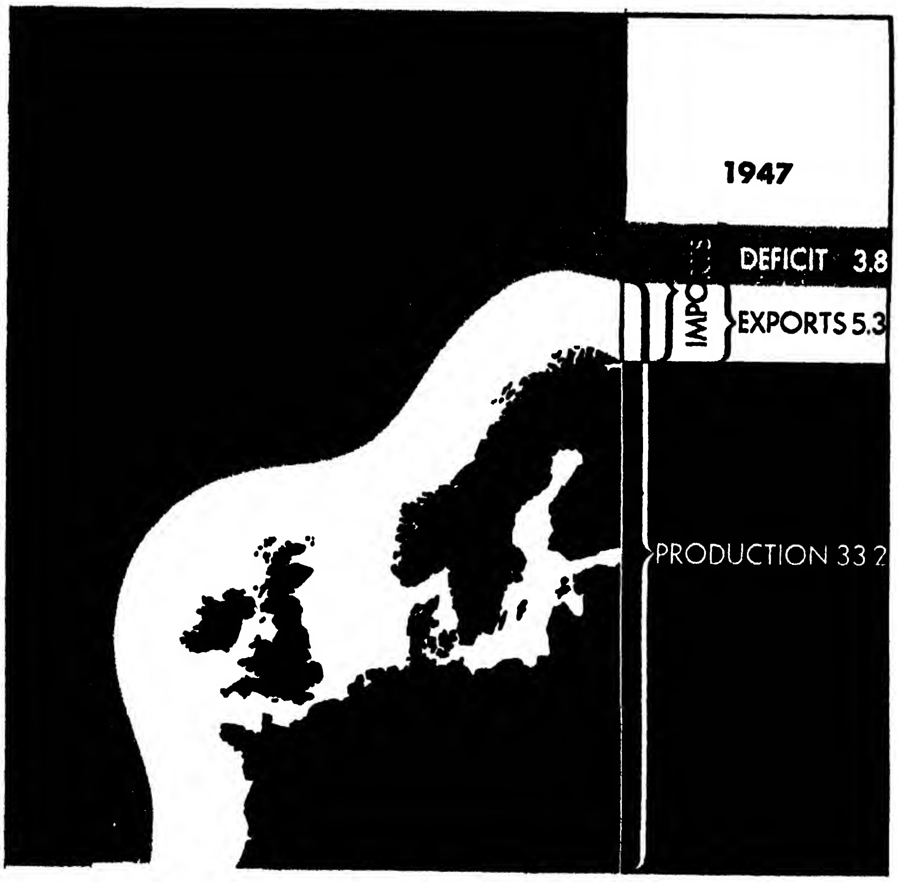
IN THE 38 MONTHS since VE Day, Europe has made a remarkable recovery. This recovery, overshadowed by political events, has been largely unheralded, but it is solidly shown in the record of production. The industrial output of the Continent, excluding defeated Germany, has already reached prewar levels. The record is particularly impressive in those industries—iron and steel, chemicals, machine tools and heavy construction which are the underpinning of Europe's economy. By the third quarter of 1947 these industries had surpassed the levels of 1938, Europe's last prewar year.

Comparison with the aftermath of the First World War gives the measure of this achievement. The Second World War lasted longer, killed more people, devastated greater stretches of territory and consumed a much larger percentage of

RECONSTRUCTION IN FRANCE has brought production of large refinery at Petite-Couronne back to 400,000 tons of petroleum products per year. Dependence upon overseas oil sources is a weakness in recovery plans.

EUROPE'S DEFICIT (MILLIONS OF 1938 DOLLARS)

Excess of imports over exports is the core of the European recovery problem. "Invisible exports," *i.e.*, the income from foreign investments, tourism, shipping, etc., covered the $2.1 billion excess of imports over exports in 1938. The wartime loss of invisible revenues leaves the larger 1947 deficit uncovered.



the Continent's wealth. In the wake of prolonged enemy occupation the civil organizations of 13 European nations were left in chaos. Nonetheless, all of Europe except Germany has bounded back to prewar industrial production levels in less than half the time required for equivalent recovery after the First World War. Even if Germany is included, the Continent's industrial recovery index, 86 per cent of 1938, exceeds the 75 per cent recovery achieved in the comparable period after the First World War.

The comparison holds good for other departments of European economic life as well. Food production, railroad carloading and exports all show a much higher rate of increase. All indices plainly indicate that this time the recovery of Europe is far better organized and planned than after 1914-18.

I. The Deficit

Europeans have not, however, taken time off from their labors to celebrate. There are dangerous weaknesses in their convalescence. Their standard of living, particularly in nutrition, has not yet recovered greatly from its wartime decline. They are confronted, furthermore, with a new and menacing problem which they did not face after the First World War. It is expressed succinctly by the $7.5 billion deficit in foreign trade that was entered on Europe's books in the year 1947: the Continent had to import $7.5 billion more than it was able to pay for by its exports to other countries. (*See charts at left.*) It must incur an even larger deficit during the coming year, and must sustain substantial losses year after year for a long period thereafter.

The foreign-trade deficit has a hard and practical immediacy. In Paris, it bears directly on whether businessmen can meet next week's payroll. England faces starvation as well as unemployment if it cannot import food and industrial raw materials. For the Continent as a whole, return to prewar standards of living depends ultimately upon finding some way to pay for essential supplies from overseas. Finally, since the nations of Europe, as the world's largest producers and largest importers and exporters of merchandise, were the center of gravity of the prewar world economy, their deficit in international trade has repercussions in national economies the world over.

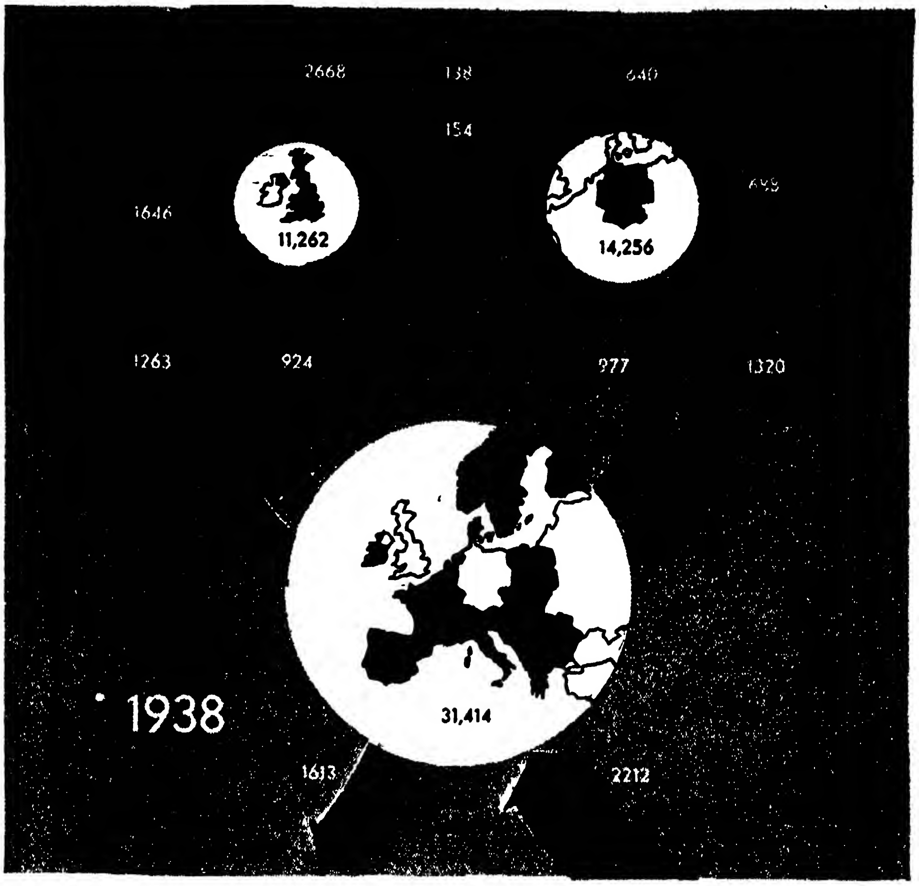
Europe's deficit is only partly accounted for by the short-term requirements of postwar rehabilitation and relief. In a much larger measure the deficit's causes are historic. Europe long ago ceased to be a self-sufficient continent. Since the beginning of the Industrial Revolution it has imported more goods from overseas than it has exported. Its population for many years has exceeded the capacity of its crowded land area to grow food. Its industries have depended upon

the rest of the world to supply them with raw materials.

In the past Europe has paid for most of its imports by exporting manufactured goods. But its tangible exports have rarely paid in full. Before 1939 the resulting deficit was covered by "invisible exports." Europe paid the deficit in part with the cash income from the riches which it had accumulated overseas during the centuries of its imperial history. (For example, Britain in 1938 held $2.7 billion worth of assets in U. S. natural resources and industries.) It paid the rest in services: tourist trade, shipping, world-wide banking and insurance. In 1938 all these yielded a net revenue of $2.1 billion.

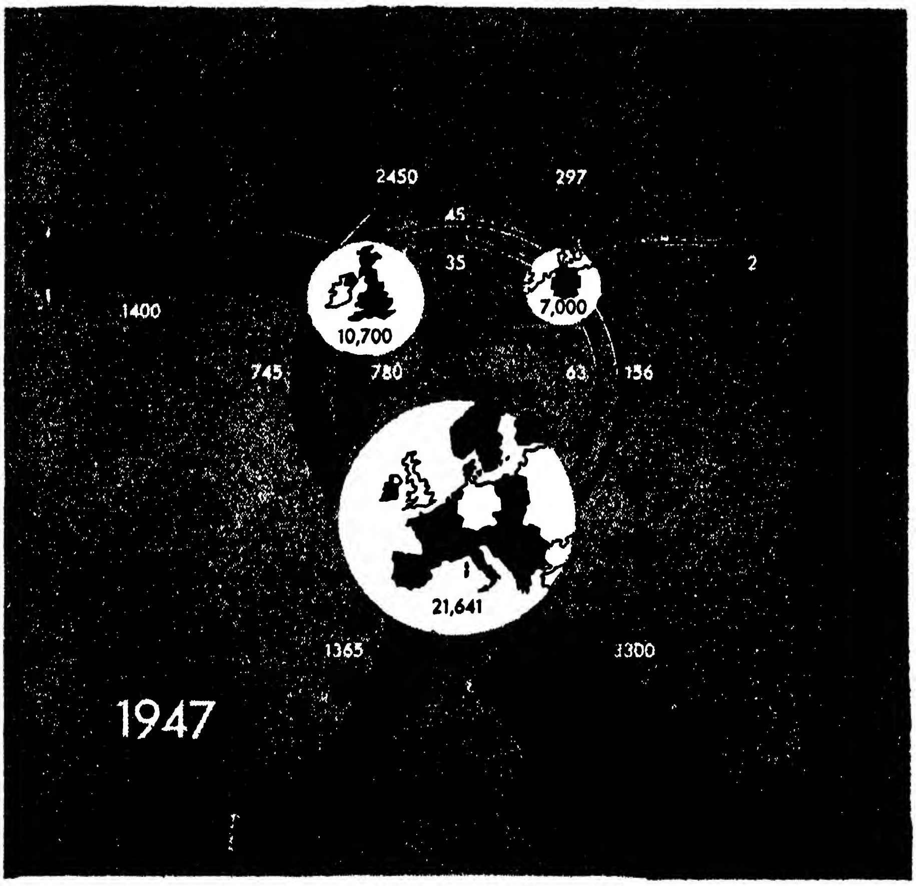
Today Europe's overseas investments have very largely been liquidated. (Britain's assets in the U. S. are down to $58 million.) The European merchant marine is ruined. Tourism is in the doldrums. London, Paris and Berlin have yielded their leadership in world finance to New York and Washington. To make matters worse, the European countries had to make heavy outlays in 1947 for the hire of foreign merchant vessels, chiefly U. S., and for overseas military operations, particularly in the Near East and southwest Pacific. Invisible exports therefore became "invisible imports" in 1947, adding a net total of $600 million to Europe's international deficit.

Thus the dimensions of Europe's problem are clear. Its current $7.5 billion deficit represents (1) emergency needs for relief and reconstruction, and (2) a long-range need for sources of income to replace its lost invisible revenues. An exact breakdown of the deficit between emergency and long-range requirements is difficult; if it is assumed that Europe's present "normal" deficit is no greater than prewar, that $2.1 billion deficit is now $4.4 billion in 1947 dollars. To achieve solvency without permanent sacrifice of its prewar standard of living, Europe must ultimately close this wide gap. It is unlikely to regain its former invisible revenues in anything like the prewar volume. To close the gap, Europe must increase its prewar exports by 56 per cent, or cut imports by 36 per cent, or (more likely) arrive at an equivalent combination of import reduction and export expansion. It must do this in the face of the fact that the U. S. is not now a customer for European manufactured goods and that other non-European countries with which the Continent might trade also have an unfavorable balance with the U. S., so that Europe cannot obtain from them the dollars necessary to discharge its huge deficit *vis-à-vis* the U. S. With world markets for consumer goods shrinking as the result of overseas industrialization, it appears that the most effective way for Europe to re-establish its foreign markets is to expand its heavy industries. It is estimated that to close the deficit gap Europe must ultimately increase its heavy



EUROPE'S TRADE (MILLIONS OF 1938 DOLLARS)

Flow of trade was maintained in 1938 by Britain and Germany. The rest of Europe financed its excess of imports from Germany by an excess of exports to Britain. The German economic collapse and Britain's loss of "invisible exports" (*see diagrams on opposite page*) paralyze Europe's trade in 1947.



industries exports by about 100 per cent.

But first it must meet the immediate postwar emergency. To a considerable extent, the Continent's short-range and long-range problems overlap, but its recovery plans can conveniently be considered in two phases.

II. Short-Range Problems

The major immediate problems following from the war are: Germany, food, inflation. Of these, the most dramatic is the economic collapse of Germany. In 1938 the German people, representing 15 per cent of the European population, produced 25 per cent of Europe's manufactured goods. They were the largest suppliers of manufactured goods to the rest of Europe and, in turn, the largest buyers of food and raw materials. Today German production is little more than one third of its prewar level. Intra-European trade, in consequence, has fallen to 47 per cent of the 1938 level. Germany's prostration is not due solely to its defeat in the Second World War. The First World War cost Germany a commanding economic position in the European economy which it never entirely regained. Despite its extraordinary comeback during the period between wars, the German economy steadily lost ground in relation to its neighbors. Since Germany is not expected to make nearly the same comeback this time, the absolute and relative decline of German output must be compensated for by an increase in the industrial capacity of other nations.

From the point of view of the average European, food is of course the most urgent problem. A poor harvest in 1946 and an untimely drought in 1947 have held the Continent's food production to a level less than 75 per cent of that in 1938. The decline in food production is greatest in the eastern European countries, which before the war were Europe's principal food exporters. Because the decline has been considerably greater in meats and fats than grains and other carbohydrate constituents of the food supply, the European diet has suffered in quality even more than in quantity.

The inflation problem vastly complicates the measures that must be taken to deal with Europe's other difficulties. Because of currency inflation, Europe's exports, so vital to its recovery, go into the world market under a serious competitive handicap, and the Continent is suffering a crippling dollar shortage. Within Europe inflation hampers production and tangles the web of trade. It dries up credit and forces nations into separate, bilateral trading arrangements with one another that require a strict export-import balance in each case. It stimulates business in nonessentials, such as jewelry, cosmetics, couture, furs and wines. It diverts steel from much-nee[illegible]ractors to automobiles. Most European countries have found it necessary to erect import barriers against traffic in luxuries, yet the same countries have also adopted the device of the tie-in sale in order to force surplus luxury goods on their customers. A country with grave reconstruction problems may have to exchange part of its limited exports for lace in order to get a little machinery. The European nations have thus been led into the position of consuming one another's luxuries. Sweden and Denmark, for instance, trying to conserve steel for exports, severely restrict the production of vacuum cleaners for sale at home; yet under their bilateral trade agreement each agrees to import vacuum cleaners from the other.

III. Reconstruction

In attacking their recovery problems, most European governments have assumed a considerable degree of control over their respective national economies. This control extends, in varying degrees, to prices, foreign trade, the allocation of scarce materials and, in some cases, to the distribution of manpower. Even those governments which refrain from active intervention in current business operations accept major responsibility for capital investment. A large percentage of new investment is directly financed by government, and private capital investments are, in the majority of countries, directed by the state through controls on the long-term capital markets, on building and construction materials and on the location of new plants. Thus, as far as economic development is concerned, most countries are operating under the guidance of a central plan of some kind.

In general the plans are directed at solving the short-term aspects of the deficit problem: the complications caused by inflation, decline in agricultural output and the disappearance of Germany as Europe's producing and trading center. (*See* Forecast of European Production, *page 15.*) Most of the plans look to 1951 as the target year. By that time the European nations hope to bring their agricultural output up to 1938 levels. The industrial objectives are far more ambitious: a 50 per cent over-all increase in the output of the heavy industries of western Europe (excluding Germany). Germany will be displaced as the center of gravity, and part of its former surplus of industrial power redistributed among its neighbors on the east and west.

The stepping up of heavy industries will give Europe a new role in the world economy. Textiles and other consumer goods will give way in Europe's exports to industrial equipment and capital goods. Europe will thereby create overseas competition for the spinning mills of Lancashire and Lyons. But that competition is already foreshadowed by the worldwide trend toward industrialization. By exporting capital equipment instead of consumer goods, Europe will take advantage of the trend to re-establish itself in the world market.

The deficit of the Continent today, as always, is largely the deficit of western Europe. The plans of the western nations are therefore predicated upon overseas aid. Since they are among the world's most highly industrialized nations, their plans are focused first on the sources and distribution of energy, then on the basic industries such as steel, next on the capital-goods industries and finally on food production.

Coal, the principal source of industrial energy, has been the principal bottleneck in the recovery programs of western Europe. Britain, by dint of mechanization and a consequent increase in production per man-hour, managed in 1947 to restore its coal output to the prewar rate. The Ruhr, however, has lagged by 11 million tons. As a result, western Europe, once a major exporter to the world, must now import large tonnages of coal from the U. S. To meet the increased demands of heavy industry, Britain, France and Belgium are carrying through a two-billion-dollar mechanization program in their mines and are counting on the U. S. to furnish $105 million worth of equipment. Despite this effort, western Europe will still be 37 million tons short in 1951, but it is expected that Poland will ship 31 million tons of coal that year and thereby reduce the area's dependence upon U. S. mines and dollars.

The growing energy requirements of western Europe will nonetheless continue to burden the Continent's import budget, for its heavy industries will demand a huge increase in oil. Since Europe possesses only minor petroleum resources, it will have to import the bulk of this new requirement from Middle East and U. S. sources.

Percentagewise, the most ambitious program of the western European nations is expansion in electric power. It calls for an investment of $5 billion and a 100 per cent increase in power production by 1951. In addition to steam plants, nine large hydroelectric power stations are to be installed in Austria, Germany and Italy. Achievement of these goals will require heavy import of electrical machinery from the U. S.

But all other programs in western Europe hinge on steel the *sine qua non* of heavy industry. Western Europe plans to lay out $2.25 billion to achieve a 30 per cent increase over prewar steel capacity. Such an increase would make up for the curtailment of German steel production and would represent a 10 per cent increase over the prewar capacity of the Continent as a whole. This program, however, has already collided with a major obstacle. As originally projected, it assumed heavy shipments of crude steel and scrap from the U. S. Because the U. S. has undertaken to ship finished and semi-finished steel rather than raw materials, the prospects of success are clouded.

Another potential bottleneck is timber, vitally necessary to meet the goals for housing, transport and shipbuilding. The timber import requirements 25 million cubic meters annually through 1951—are only slightly above prewar. But the prospect now is that only half the requirements will be met unless the eastern European nations are able to secure timber-hauling and processing equipment which they require.

If timber and steel bottlenecks do not interfere, western Europe plans to build 621,000 railroad cars during the next four years to relieve the strain on its railways. In the field of shipping, it faces quite another problem. There are plenty of ships on the seas; the U. S. has 14 million tons of idle shipping capacity. Nonetheless, because the imbalance in Europe's foreign trade requires that it make its merchant marine again a significant earning asset, the western European nations plan to invest precious materials and man-hours in an ambitious shipbuilding program. They have been unreceptive to U. S. suggestions that the ERP countries take over the U. S. surplus of low-speed Liberty and Victory ships. Low-speed vessels with a high operating cost might permanently damage Europe's competitive position.

In the matter of food, western European nations can never be self-sufficient, but they plan to meet a higher proportion of their requirements by further mechanization of agriculture. Before the war, mechanization stood at something like six per cent of the total power used on farms (including draught animals). Last year it rose to more than 12 per cent, and further steep increases are planned. Western Europe's food output, except in meat, is to equal or exceed the prewar level by 1950-51. But the population will be at least six per cent larger, so food imports from overseas will have to continue considerably above prewar if the average European is to eat as well as he did then.

IV. Eastern Europe

The food problem points up the interdependence of eastern and western Europe in the economic unity of the Continent as a whole. As food production recovers in the East, the West's present extreme dependence upon overseas food imports will be relieved. In a typical prewar year the eastern nations exported 4 million tons of grain, 1.4 million head of

DESTRUCTION IN GERMANY has reduced its industrial production by nearly two thirds. Bremen, shown here, was one of Germany's major port cities, a center for the processing of raw materials imported from overseas. The conical air-raid shelters are only intact structures in this picture.

pigs and cattle, 87,000 tons of meat and 78,000 tons of eggs, taking manufactured products in return.

Right now, eastern Europe's food exports are negligible. This is partly because of the war's destruction. But in even larger measure it is the consequence of postwar social revolutions which have smashed the feudal, one-crop agricultural economy of the region. Since 1945 some 20 million acres of feudal estates have been split up into small farms; the peasant-tenant has become a yeoman freeholder. The result, for a while at least, is the disappearance of exportable surpluses of grain and beef. The resumption of exports will also be delayed by state plans of the region which call for radical changes in the structure of its agricultural economy. Farming in eastern Europe is now to be diversified—in accord, incidentally, with the recommendations of the League of Nations Nutrition Committee in 1936—with the objective of maintaining soil fertility, supplying a balanced diet to the people on the land and raising farm incomes. If the new pattern of agriculture is to produce surpluses for export, there must be a big increase in mechanization.

This is the principal objective of the ambitious industrialization programs of the region. In addition, rational distribution will require the formation of co-operative or collective producing and marketing organizations. Diversification of output will bring important changes in the composition of eastern Europe's food exports; grain shipments will fall off in favor of meats and fats, canned fruits and vegetables. In line with these objectives, the western European nations are expected to provide substantially increased supplies of fertilizer and agricultural equipment. They have already scheduled the shipment of half of their tractor output to the East during the next four years.

Hand in hand with the diversification and intensification of agriculture go even more far-reaching changes in industry. Before the war, eastern Europe was not only a feudal but also primarily an extractive economy. Its natural resources yielded only a minimum of revenue because the produce of its mines and forests was exported largely as unprocessed raw materials. In return, the East purchased the more expensive manufactured goods of its customers. The industrialization programs of the eastern European nations are designed to redress this unequal exchange. By processing their raw materials themselves, they will get greater value from their natural resources and, incidentally, provide employment for their surplus rural populations. Yugoslavia, for example, used to send Germany most of its bauxite, instead of converting it into aluminum. It also exported its copper, lead and zinc in the form of concentrates or ores. From now on it will process a much larger proportion of the metals itself and thus supply materials for the various other expanding industries at home.

Like western Europe, the East has ambitious plans for industrial expansion. For example, industrialized Czechoslovakia, the principal steel producer of the region, plans a 50 per cent increase in ingot capacity by 1953. One consequence of this program will be a sharp increase in trade among the countries of eastern Europe. There is no evidence, however, that this increase in trade within the region and with the U.S.S.R. will reduce trade with western Europe or overseas. In the first half of last year, for example, Czechoslovakia did less than 20 per cent of its trading within the region. Poland, with a 300 per cent increase in coal exports projected for 1949, is committed to send far more coal to western Europe than in prewar years.

Western and eastern Europe are interdependent. The West needs the East's food and raw materials; the East, if it is to meet its production goals, must get fertilizers and machinery for its farms, and capital equipment for its industries, from the West. This interchange is not likely to be blocked permanently by political forces that tend to divide the natural economic unity of Europe. The resumption of intra-European commerce on very much the old basis, which seems possible by the early 1950s, will bring a reduction in the Continent's dependence on imports.

But Europe's success in meeting the balance-of-payments problem will depend most of all on the success of the western nations in reaching their industrial production goals. The prospect of attaining these goals is fairly bright if two provisos are met. First, trade and credit arrangements must be developed within Europe to permit a more rational utilization of the Continent's resources. (Belgium, for instance, could now export substantial numbers of railway cars if other countries could pay for them; France and Italy could easily produce more ball bearings if they could pay Sweden for the needed chrome steel.) Second, there must be no interruption in the flow of overseas supplies to Europe during the next four years. As the chart at the bottom of the opposite page indicates, the bulk of these will have to come largely from the U. S.

Assuming the success of its production program, Europe by 1951 should slash its imports-exports deficit by 50 per cent. This would mean that Europe had successfully achieved the short-term goal of recovery from the war. Its unfavorable foreign trade balance would still be more than $4 billion. Discounting inflated prices, this would be equal to the $2 billion deficit in real commodities which used to be covered by invisible export revenues. If all goes well, therefore, the Europeans in 1951 will be able to focus their energies on the long-range problem of balancing production, imports and exports in order to re-establish Europe once more as a self-sustaining unit in the world economy.

RECONSTRUCTION plans of European nations look to substantial increases over 1938 levels of industrial output and restoration of prewar production in agriculture. To bring out structural changes in the European economy, this chart takes the 1938 output of the Continent in each category as 100 per cent. The industrial decline of Germany is shown to be absolute as well as relative. Coal and steel production targets of western Europe are high enough to make up for German decline and bring over-all increase in the output of the Continent as a whole. Bigger supply of these basic materials is key to plans for a 50 per cent expansion in the output of other heavy industries. Disproportionately large increases in production of electric power indicate that European industry will move to higher levels of technology as well as higher levels of production. Industrial expansion in eastern Europe is directed primarily at increase in agricultural output and depends upon imports of industrial equipment from western Europe. Achievement of agricultural objectives will, in turn, permit eastern Europe to resume export of food to the West. Increase in eastern coal output is primarily Poland's and will help reduce Europe's coal imports from the U. S.

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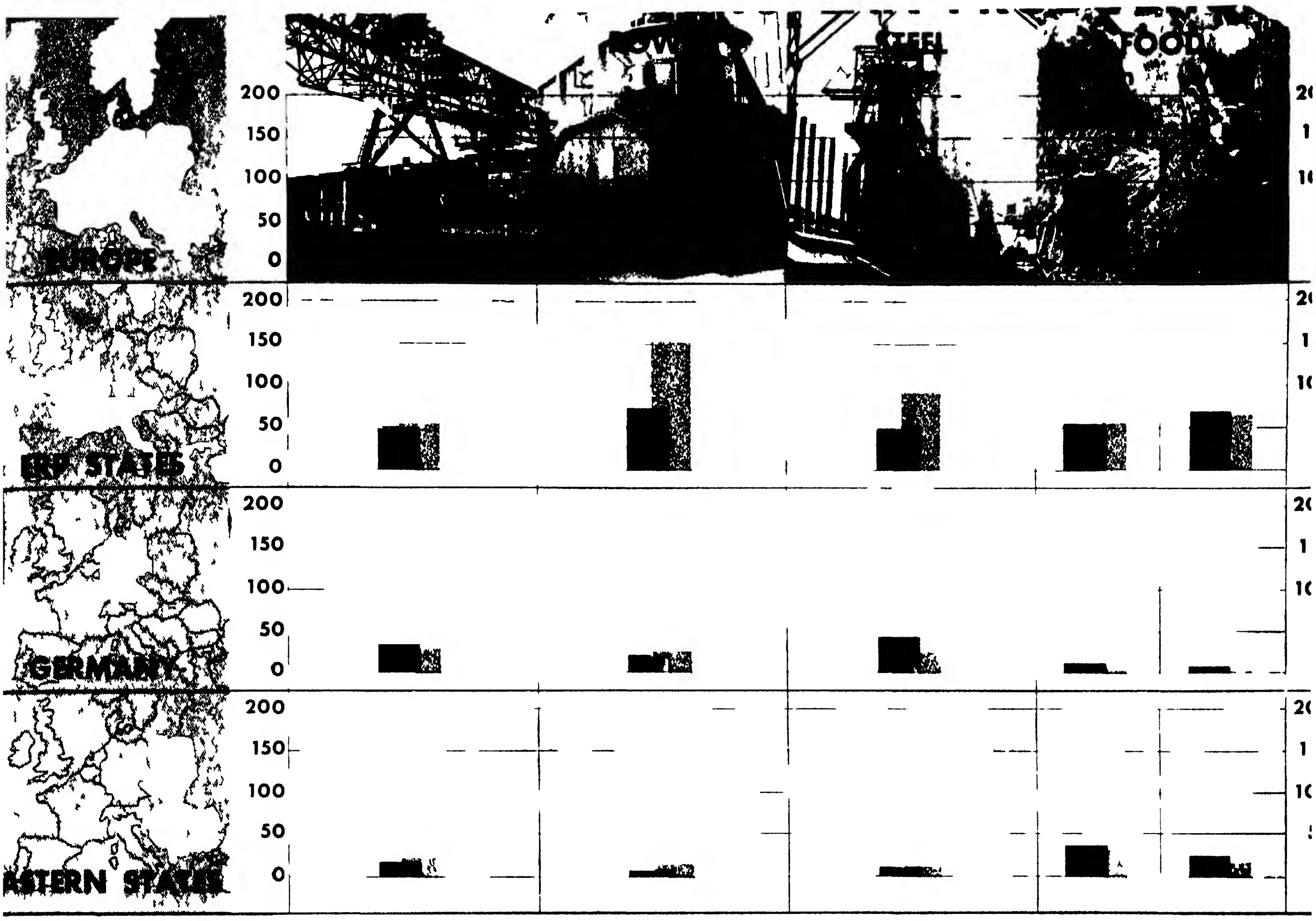
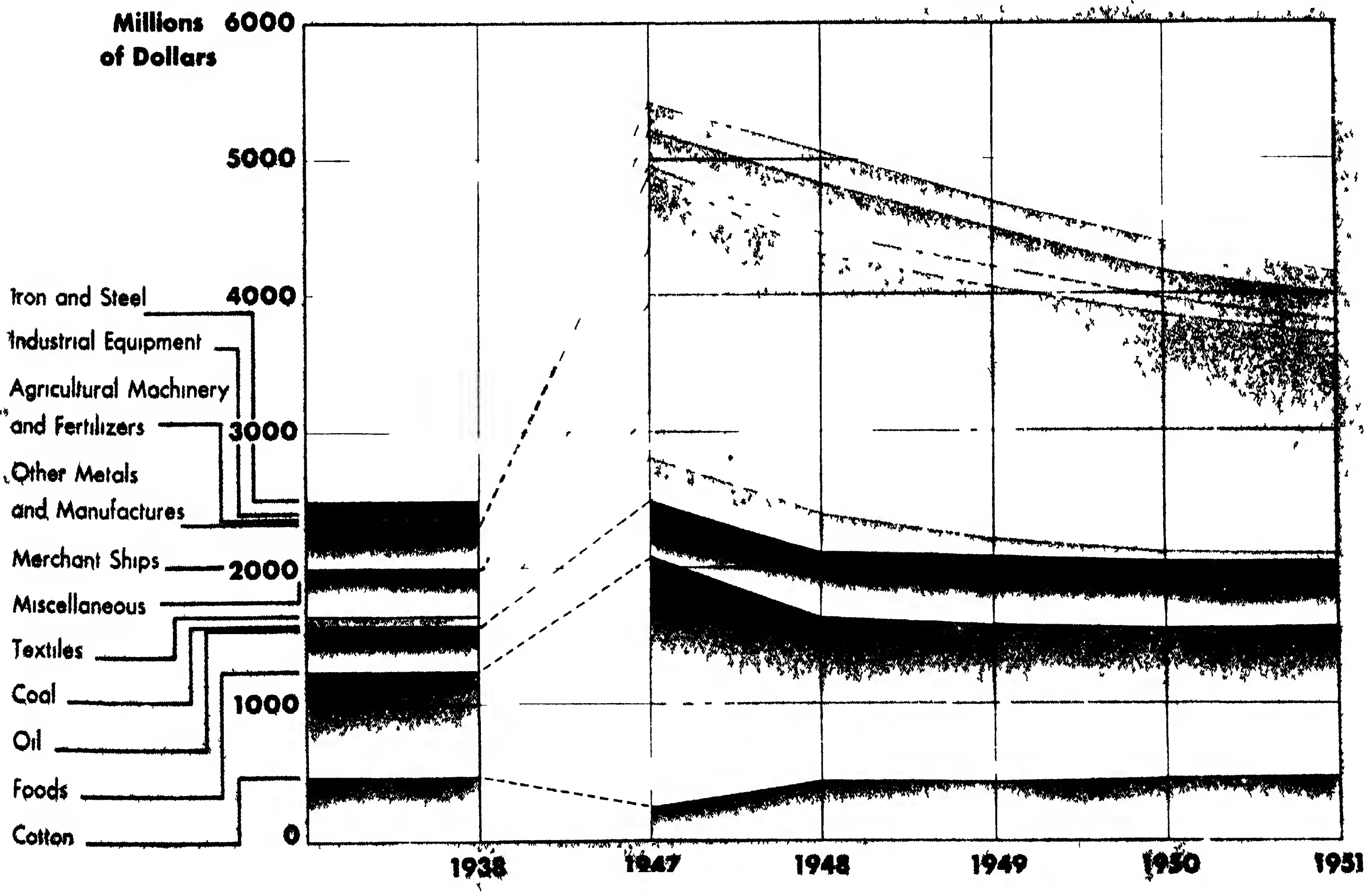
U. S. AID is critically essential to the achievement of the reconstruction plans outlined above. This chart shows the major requirements as forecast at the Paris conference on European economic cooperation in 1947 by the 16 nations participating in Marshall Plan aid. The dollar values in the chart are adjusted to 1947 prices. The gray band segregates the commodities—food, raw cotton and oil—which made up the bulk of prewar European imports from the U. S. Recovery in agriculture will substantially reduce European dependence upon the U. S. during the next 12 months. The commodities in the red band are those required to meet the demands of Europe's present emergency and for reconstruction. Principal emergency items are coal and finished textiles, which were minor items in prewar trade and which will decline sharply during the forecast period. The bulk of the remaining categories—iron and steel, industrial equipment, machinery and other metal manufactures—will go into the reconstruction and expansion of Europe's industries and will help to reduce all other categories of imports from the U. S. The first Marshall Plan appropriation by Congress last month met the $5 billion need forecast for coming year.



FORECAST OF IMPORTS FROM THE UNITED STATES



ANTIQUITY OF MODERN MAN

The discovery of a broken skull in a French cave proves, after a long debate, that Homo sapiens walked the earth with Neanderthalers

by Loren C. Eiseley

TEN SKULLS of Ice Age Europe, covering roughly the period from 50,000 to one million years ago, have baffled a generation or more of geologists and anthropologists. The mystery concerns the fossils' age and this, in turn, affects the entire question of how the human line has evolved. The key questions in the mystery are whether the beetle-browed Neanderthal man was really our ancestor or an unhappy cousin doomed to extinction, whether *Homo sapiens* is a recent arrival or a hardy species that has stood the test of evolution for several hundred thousand years. In short, how old is modern man? How far back can his characteristic features—our features, the friendly faces that greet us at the club—be traced?

One man gave up a major part of his career to working on the puzzle and finally—in the closing years of his life—became convinced that his theories were mistaken—though time was to prove him right. Those 10 grinning skulls have seen the right men wrong and the wrong men right for five decades.

Last August, in a quiet French village, the mystery was solved. In the cave of Fontéchevade in the Department of Charente a few fragments of an old skull were brushed carefully out of the ancient clays. The world press gave it no notice. There was no battery of cameras, no one spoke over the radio about "missing links." Indeed, there was no reason why anyone should. It was an old skull and very broken. The only curious fact about it was that it was a skull very much like your own.

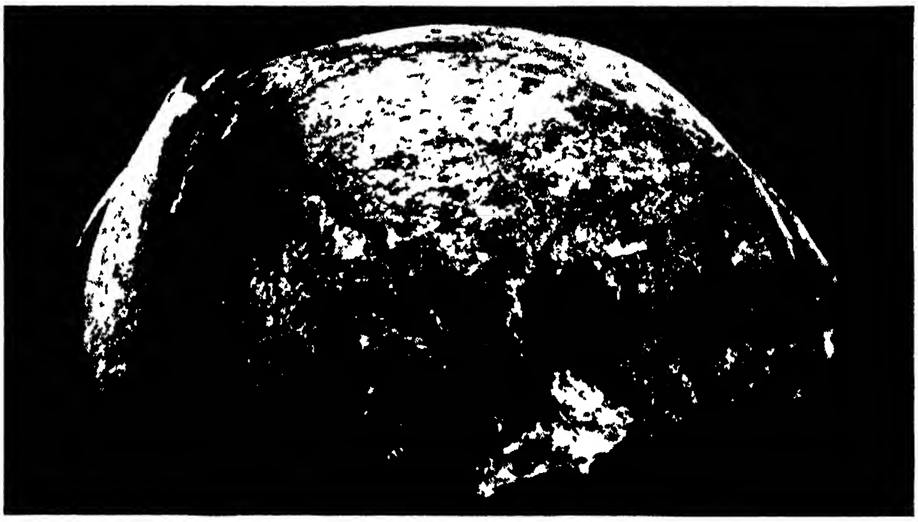
To an anthropologist, that was astounding enough. The great French prehistorian Henri Vallois came and marveled. A few letters were exchanged among scientists. One whose theories had been blasted protested harshly that there must be some mistake. Before there had always been some reason to dismiss such findings as the fumblings of amateurs or an accident of nature that had misplaced the fossils. But this time there could be no mistake, and the doubters grew angrily silent. It was the end of an era, and a new interpretation of human history was now in order.

At Fontéchevade Mademoiselle Henri-Martin, a quiet, amiable French scientist, daughter of a famous archaeologist, continued to busy herself with the restoration of the skull she had discovered. No inquiring reporters intruded, and it was just as well. After six years of laborious effort in the earth one did not want to be hasty; one should establish one's evidence beyond doubt. The evidence was clear; and this time of all times the right people were present.

The story of the skull is a strange tale out of the past—the story of a human being dead when now-extinct elephant and rhinoceros species roamed the environs of Paris. Like all true stories, it is difficult to tell because the threads are many and lead to strange places and even stranger characters. You can say it began with Darwin or the priest MacEnery, or with the eccentric American doctor Robert Collyer. It is all of this and more, because it concerns man's infinite yearning to know the truth about himself, and that truth he will never possess until he has trekked backward into time far enough to see his own footprints merge humbly into those of the lesser beasts.

Archaeology is just a little over 100 years old, and in that century, man's notions about his history have altered tremendously. Looking back, we can discern two periods of firmly held preconceptions about human origins and we can see also their successive rejection. Three episodes sketch the stages through which this controversy has passed.

A little over 100 years ago, a Catholic priest, Father J. MacEnery, began to carry on some excavations in Kent's Cavern, a famous old cave in the south of England. One has to know something of the history of archaeology to catch the irony of this situation. The time was one in which the Biblical conception of creation still reigned. Mankind, it was thought, could be no older than 6,000 years. Georges Cuvier, the great French paleontologist of the time, is reputed to have tossed out of the window in disgust a human jaw brought to him by someone who thought it associated with fossil animals of the distant past. Scientists and laity alike slapped their thighs and roared with laughter at the ideas of lunatics who talked about tools and bones older than the world itself. Nevertheless that world was changing. Strange things had been found in caves in Germany and France—unbelievable things, of course—but Father MacEnery was curious. He left his contemporaries chortling in their taverns and set out with a shovel to investigate.



CHARENTE MAN, discovered by Mademoiselle Henri-Martin in the cave of Fontéchevade, is represented by broken brain pan. Added evidence that it is *Homo sapiens* is provided by fragment of another skull found with it.

In the echoing galleries of the cavern, behind the town of Torquay, the priest found his answer. From the cavern floor he unearthed implements of stone and

bone lying in the same stratum with the bones of extinct animals—the great cave bear, the mammoth, the rhinoceros Father MacEnery, Roman priest, had stepped across an invisible threshold; he had entered the Pleistocene.

It is true he was not quite the first to dig in the English caves Dean Buckland, then reader of geology at Oxford, had dug at Paviland Then in his *Reliquae Diluvianae* of 1823 he had given the lie to all he had seen by maintaining that the strange associations of men and beasts he had found were the result of human remains that had been swept into the caves at the time of the universal Deluge. Dean Buckland was an authority He had reconciled theology and science.

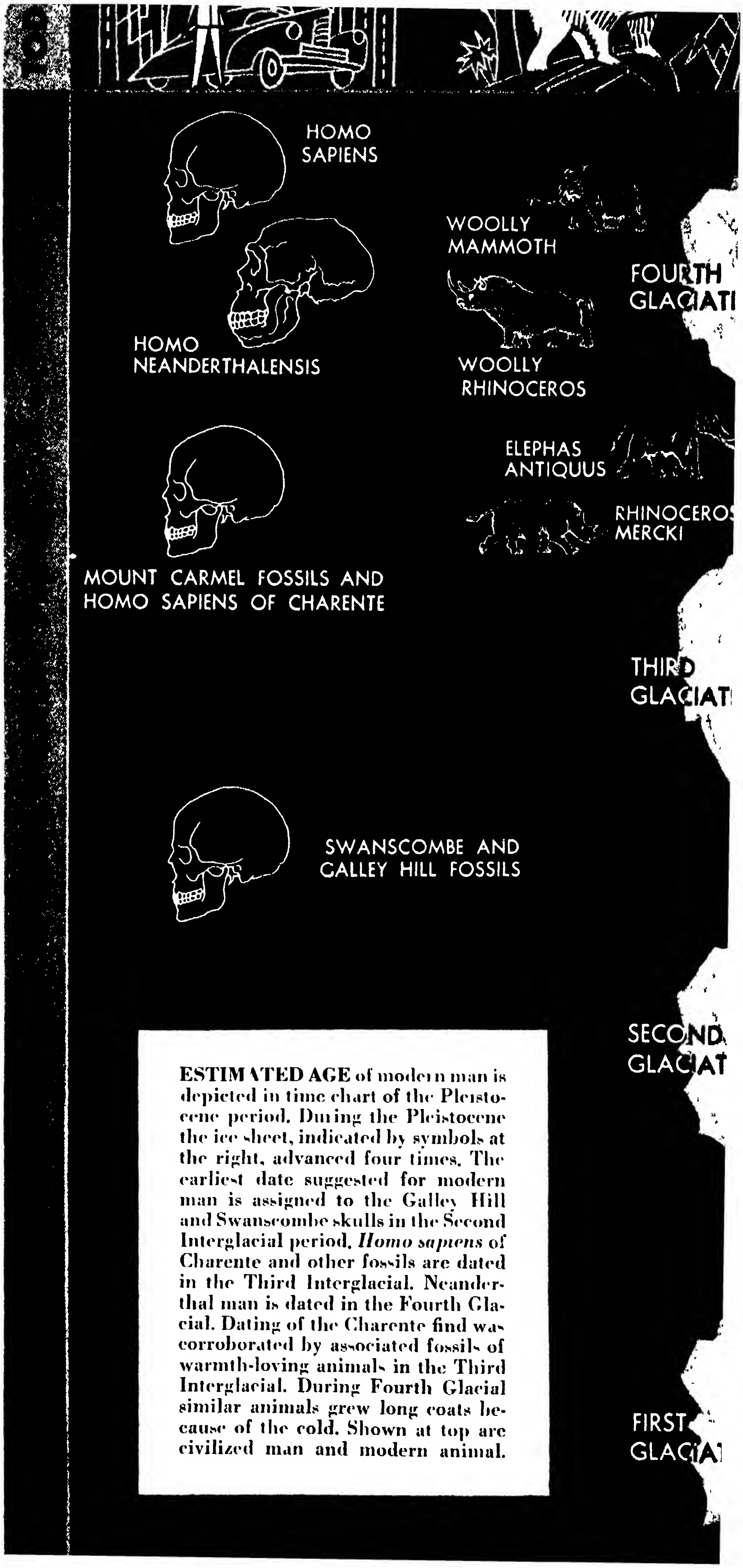
But MacEnery shook his head. No, he maintained. The evidence pointed otherwise Men had lived here long ago Men had lit their fires here and cooked their food. Men far away in time, contemporaries of the great gray mammoths

Father MacEnery spoke, but the Dean thundered He was the leading authority on caves Someone took Father MacEnery aside. Someone must have said to him "My dear fellow, this controversy is growing public Consider your cloth, consider your vulnerability, consider your position"

Father MacEnery did consider He laid aside his book in manuscript His beloved *Cavern Researches* was not published until long after his death He dug no more Only in the loneliness of his own fireside and without companions could he relive again that magnificent moment when, first of all mankind, he had lifted up his torch and looked full into the world of the ice

It was 30 years before science accepted what he had seen in that blinding vision Father MacEnery had lived in a primitive period - the world of little time At the end of a cavern he had found the way out He did not survive to see his views accepted, he never realized that in the vast depths of time he had uncovered there shambled uncouth and anthropoidal men He knew only that for a single moment in Kent's Cavern time had suddenly opened out like space and that nothing had seemed quite the same afterward It took the rest of the century and the long thought of a biological genius, Charles Darwin, before the idea of eons of time became acceptable, and the bodies of men and animals were seen to melt and flow and change from age to age like the hills they moved upon

EVEN THEN, perhaps the vision was still beyond us. The human mind always tends to erect new dogmas, to shelter itself in hastily erected systems against what is not known or what proves at last to be unknowable The forms of paleoanthropic, big-browed fossil men began to be discovered. Though their numbers were few, scientists fitted them into a system—a single line of ascent leading to modern



ESTIMATED AGE of modern man is depicted in time chart of the Pleistocene period. During the Pleistocene the ice sheet, indicated by symbols at the right, advanced four times. The earliest date suggested for modern man is assigned to the Galley Hill and Swanscombe skulls in the Second Interglacial period. *Homo sapiens* of Charente and other fossils are dated in the Third Interglacial. Neanderthal man is dated in the Fourth Glacial. Dating of the Charente find was corroborated by associated fossils of warmth-loving animals in the Third Interglacial. During Fourth Glacial similar animals grew long coats because of the cold. Shown at top are civilized man and modern animal.

man. A form like Pithecanthropus, for example, led on in the following age to Neanderthal man, and the latter was regarded as our own direct ancestor. At the other end of the succession, the beginning, was an ape generally conceived of as differing little from a modern chimpanzee.

The sequence was thought of as short and very direct. The time scale was still being underestimated, and western Europe, actually marginal to the Asiatic land mass, was unconsciously overemphasized as an evolutionary center for mankind. In addition, certain preconceptions were making it difficult to survey the problem of the origin of modern man in an unprejudiced light.

The most obvious of these preconceptions was, of course, the idea that since the remains of Neanderthal man had been found in European deposits immediately underlying our own species, we must be a later breed. Thus there could be no valid remains of *Homo sapiens* that were as old as Neanderthal man in Europe. Aleš Hrdlička, for example, in his Huxley Me-

GALLEY HILL skull, found in a terrace of the Thames, may date back 400,000 years. But because it was uncovered by amateurs, its authenticity has never been completely accepted.

morial Lecture of 1927 at London, scoffed at the idea that modern man might have developed before Neanderthal. In his mind there was no doubt that Neanderthal man, placed in the Mousterian period some 100,000 years ago, had slowly been transformed into a creature like ourselves sometime during the middle of the last great ice sheet. The final transformation he attributed, rather crudely, to the selective effect of a rigorous glacial climate.

Curiously enough, however, almost from the beginning there were faint clues that pointed in another direction. For illustration the case of Robert Collyer might be cited. He was an American physician residing in London and actively interested in everything from hypnotism to bones. Intrigued, perhaps, by the Darwinian controversy, he purchased a human jawbone and published a paper about it in 1867. The fossil was submitted to T. H. Huxley and other famous authorities of the day. None seems to have been particularly impressed.

Collyer's claim for the antiquity of his specimen lay in its fossilized state and the fact that it had been obtained from a gravel pit near Foxhall at a depth considerably below the surface. Perhaps the fact that it had once changed hands for a glass of beer did not inspire confidence in its origin. At all events, after it had passed under many eyes, interest waned, *largely because the jaw was modern in appearance.* The disappointed doctor is believed to have turned homeward to America. With him went the Foxhall mandible. Together they vanish from the sight of science. An engraving of the jaw which has come down to us, however, suggests that it did indeed look like modern man's.

THE IRONY of the tale lies in the fact that long, long afterward, in 1922, the English archaeologist Reid Moir relocated the old Foxhall quarry and established an early Pleistocene cultural horizon within it. If the jaw actually came from this level, as Moir believed, we would have undoubted evidence that a form of man like ourselves was wandering on the European continent long before the time of Neanderthal man.

Now of course such a striking reversal of all our accepted notions of prehistory can never be carried out on so flimsy a basis. The story of Robert Collyer's Foxhall jaw points a moral, however. The find was potentially one of great importance. The quarry in which the discovery was made should have been investigated immediately. Instead, so inhibiting were the prevailing preconceptions as to what an early human fossil should look like that apparently no one sought to investigate the site itself or pursue excavations there. Attention unfortunately centered on the mandible itself and, since there was nothing about it that the anatomist could surely regard as primitive, interest quickly faded. Only time will tell how many other ancient human relics may have been discarded simply because they did not fit a preconceived evolutionary scheme. It cannot be too often emphasized that if the type of man that now exists should prove to be very old, only geology and the study of man's associated tools and implements will have established the fact. None of this, seemingly, was grasped at the time. Perhaps the circumstances were such that it would have made no difference. Nevertheless one wonders. And the story of the Foxhall pit continues to be told and retold wherever archaeologists gather—told with that wistful wisdom of people speaking 80 years after the event who say to themselves, "If only *I* had been there . . ."

The finds accumulated. Sir Arthur Keith, the great English scholar, catalogued many of them in his work *The Antiquity of Man* in 1925. There was the Galley Hill skull from the 100-foot terrace of the Thames, a fossil that seemed to date back as far as the Second Interglacial, some 400,000 years ago. It, too, was found by amateurs. It, too, failed to gain unqualified acceptance, though it was vigorously defended by Sir Arthur. There were other finds in France, in Italy and again in England. Always the doubt remained. Nor was it all mere prejudice. Our dig-

FOXHALL JAW, supposedly found in an English quarry, was publicized by the American physician Robert Collyer in 1867. If authentic, it might have dated back to early Pleistocene.

ging luck had been bad. When one finds a Neanderthal man, one knows one is handling ancient material. With our own human type, the bones may tell nothing or may speak in riddles. We must have other evidence of an irrefutable character.

Sir Arthur recognized this when he wrote, a little wearily, of the Galley Hill specimen: "The anatomist turns away from this discovery because it reveals no new type of man, overlooking the much greater revelation—the high antiquity of the modern type of man, the extraordinary and unexpected conservatism of the type. The geologist regards the remains with suspicion for two reasons—first, he has grown up with a belief in the recent origin, not only of modern civilization, but of modern man himself. He expects a real anatomical change to mark the passage of a long period of time. . . . Moreover, a very primitive type of man survived in Europe. . . . Hence the rejection of all remains . . . which do not conform to this standard."

There the argument stood. The Peking men were discovered—low-browed, small-brained, more primitive than Neanderthal. Their datings were not much older than the time suggested for the Galley Hill skull. Yet to imagine these two forms as standing so close to each other on the time scale with the one directly ancestral to the other strained credulity. The authenticity of the Galley Hill cranium seemed even less plausible than before. Then, in 1935 a strange thing happened. In a gravel pit at Swanscombe, England, 24 feet beneath the surface, the fragments of another skull were found.

The details of that discovery need not

detain us. Here we are concerned only to note that these fragments, which unfortunately did not include the face or forehead, suggested very strongly a true *Homo sapiens* type. And this was associated with the Acheulean culture in geological deposits dated in the Second Interglacial! By comparison, Neanderthal man was alive just yesterday. There was no reasonable doubt of the skull's position, no reasonable doubt as to its geology or the sort of tools found with it. The anatomist W. E. Le Gros Clark allowed that the skull gave evidence that already in early Paleolithic times the human brain had "acquired a status typical of *Homo sapiens*."

Nevertheless, the evidence was not complete. The face was missing. Were we sure, after all, that the face was like our own? Might it not have carried the heavy brow ridges of at least an advanced Neanderthal type? To confuse us further, finds in Palestine, at the much later date of the Third Interglacial, something over 100,000 years ago, suggested a Neanderthal type evolving in the direction of *Homo sapiens*. It was either that or a hybrid mixture between an already existing modern type of man and his heavy-browed relative. Once more argument raged. Even Sir Arthur Keith seemed to waver in his espousal of the antiquity of modern man. It is, then, by this involved and twisted pathway that we come to Mademoiselle Henri-Martin and the deposits in Charente.

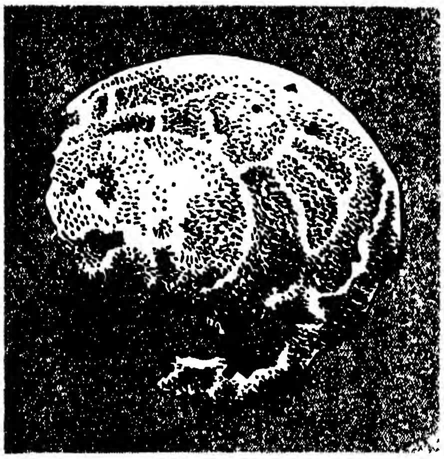
The cave lies at the side of a small valley near the village of Montbrun. It had long been known to students of prehistory as having yielded a succession of stone industries extending from Mousterian times to the much later Magdalenian period of the post-glacial era At the base of the Mousterian cultural layer everywhere associated in Europe with Neanderthal man- earlier workers had struck a solid floor of stalagmite There they had stopped.

Mademoiselle Henri-Martin was not so easily deterred. Near the mouth of the cave she broke through the stalagmitic floor and found, in the red, sandy clay underneath it, an older, cruder flint industry marked by large flakes which the French prehistorian Henri Breuil has termed Taycian. It is regarded as a flake culture transitional between the Mousterian and an earlier period.

Many cultural horizons contain no human remains, but here, abandoned among flint chips and the bones of animals, lay a human skull. One can imagine the eager brushing away of earth, the careful manipulation of tools. Here, certainly, must lie an ancestral Neanderthal. This is the Third Interglacial time. The long, cold night of the Fourth Glacial is still far away in the future.

The skull is too worn, too delicate to free quickly from the encasing earth. The hours go on. It is seen not to be complete; finds of such great antiquity rarely are. Nevertheless, the two parietal bones forming the major part of the sides of the head appear. Part of the occipital bone at the back becomes visible, and a fragment of the frontal. It is not, however, the part of the frontal that can tell us about the brow ridges. But for all that, this skull has an oddly familiar look.

In the bony debris painstakingly gathered by the workers, another human fragment is discovered—a very odd fragment that might easily be tossed aside by the inexperienced. Apparently belonging to a second individual, it is the final key to a story that might otherwise have ended like the debate over the Swanscombe skull This is a glabellar fragment—a little piece from just over the root of the nose and including a little part of the orbit of the eye. There is no trace of a brow ridge The orbital edge has the delicate sharpness of a modern woman's. This is *Homo sapiens!* This fossil woman saw with living eyes the warmth-loving fauna of the Third Interglacial. In the trench with her lie scattered the remains of *Rhinoceros merchi* and a warmth-loving Mediterranean turtle. The woolly mammoth and the woolly rhino of the last glaciation have



SWANSCOMBE SKULL, also found in England, is dated in Second Interglacial. Its identification as a fossil of modern man, however, is difficult because brow ridges are missing.

not yet come. In the opinion of Henri Vallois, the fossil seems to validate the authenticity of the Swanscombe discovery and, over and beyond, to confirm the existence of a non-Neanderthaloid type on the Continent prior to the Mousterian period.

The skull is markedly long-headed—hyperdolichocephalic, as the anthropologists say. The thickness of the skull bones is marked but not excessive. It is a small skull within the size range of living females. There is nothing Neanderthaloid about it. This woman could have sat across from you on the subway yesterday and you would not have screamed. You might even have smiled.

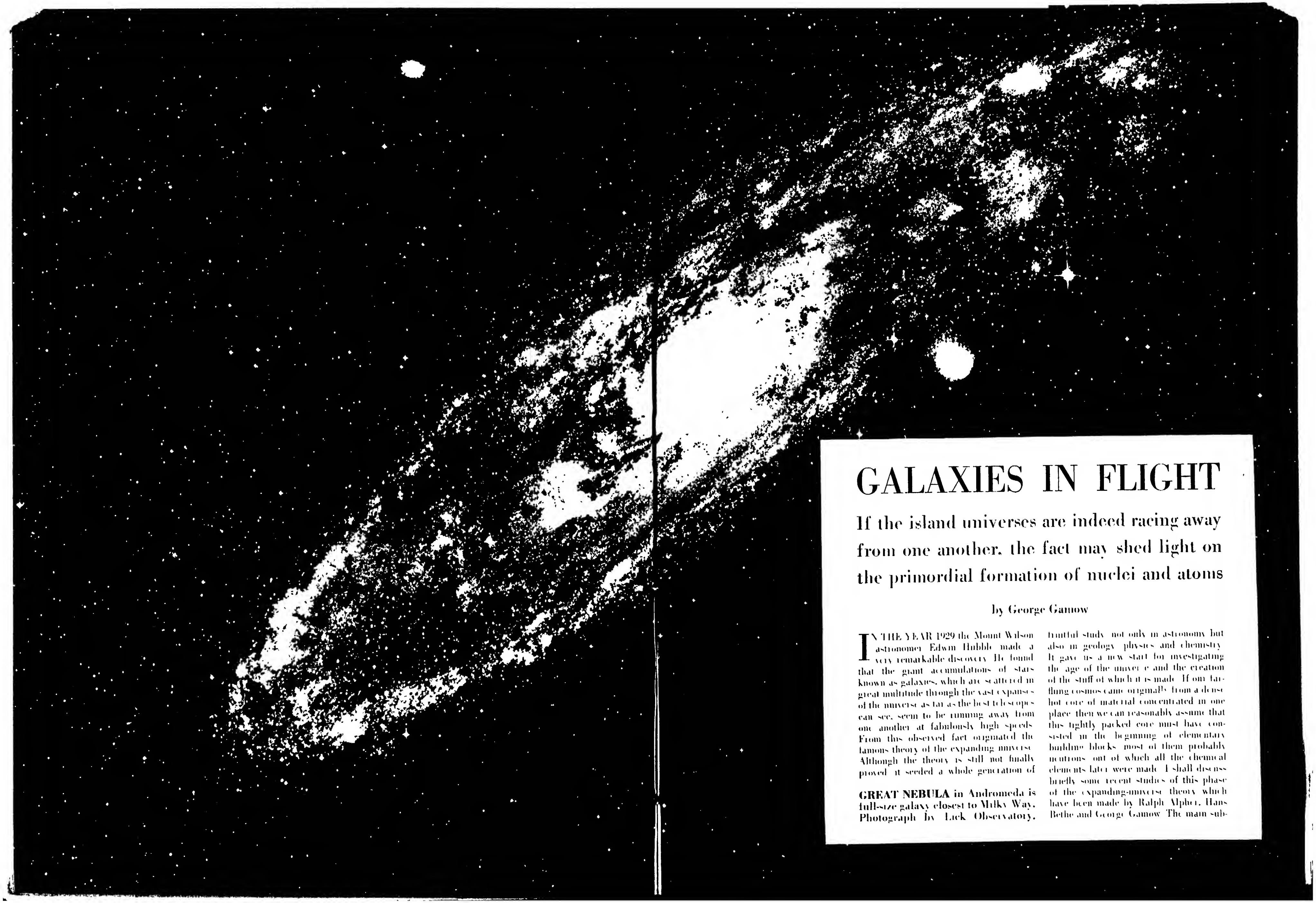
AGAIN and again, in the case of previous discoveries, the question of intrusive burial had arisen—the possibility, in other words, that the bones were younger than the cultural stratum in which they were found. But Dr. Hallam Movius, a leading authority on the Old World Paleolithic, says: "There can be no question concerning the fact that these finds were *in situ* [in their original site] when discovered by Mademoiselle Henri-Martin: they come from an undisturbed horizon sealed below a thick, unbroken and continuous layer of stalagmite that underlies the Mousterian level at this locality. Furthermore, the fauna demonstrate that these deposits were accumulated under conditions of the warm temperate climate of Third Interglacial times. And the archaeological material is definitely older than the Mousterian from a typological point of view."

Frederick Zeuner, the geochronologist, once wrote that the Pleistocene is a period characterized more by extinction than by creation; that it takes something like 500,000 years for one species to diverge clearly and recognizably out of another. The Pleistocene covers a scant million years. Have we expected too much to transpire in it? Is our vanity offended because, in spite of the great age of our race, it is only in the lattermost part of that epoch that our cultural activities have taken on a highly creative character? Has man, the living species, or something very closely approximating him, drowsed through endless millenia a little as the Australian aborigines were doing until Western explorers stumbled upon them?

There are thousands of questions one yearns to ask, and the answers are very few. What, one might inquire, is our relationship to those thick-skulled, heavy-browed Neanderthals who seem at the onset of the last ice sheet to have dominated western Europe? Were they already "living fossils" structural ancestors of ours in an earlier time?

Darwin and Huxley certainly were not wrong in their evolutionary theory. We bear in our bodies the traces of our lowly origin. But the lady of Charente takes modern man back to the Third Interglacial of over 100,000 years ago. The Swanscombe cranium very probably carries our human type into the long summer of the Second Interglacial. Year dates grow meaningless when they begin to reach the 400,000-mark. Nevertheless, somewhere far below in the unplumbed depths of the Pliocene of one to seven million years ago, the trail converges backward. It is a trail shared apparently by giants and by dwarfs, by all manner of strange humanity. Year by year their bones accumulate in our museums. Year by year we sort and rearrange and ponder.

Loren C. Eiseley is professor and head of the department of anthropology at the University of Pennsylvania.



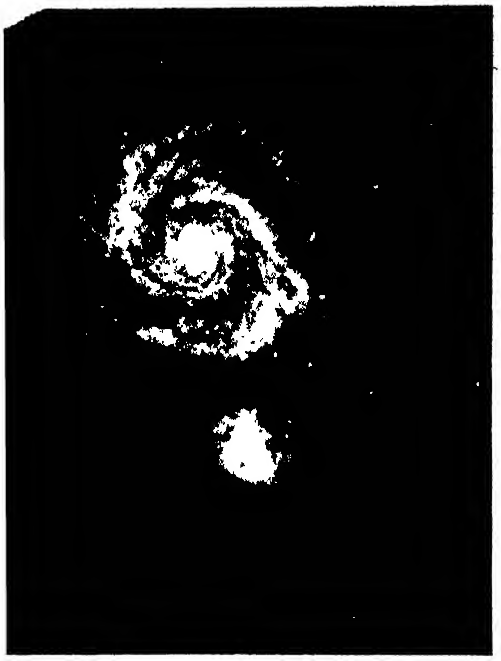
GALAXIES IN FLIGHT

If the island universes are indeed racing away from one another, the fact may shed light on the primordial formation of nuclei and atoms

by George Gamow

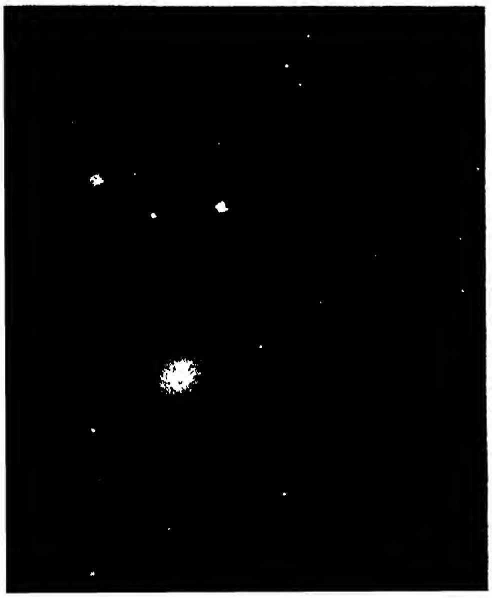
In the year 1929 the Mount Wilson astronomer Edwin Hubble made a very remarkable discovery. He found that the giant accumulations of stars known as galaxies, which are scattered in great multitude through the vast expanses of the universe as far as the best telescopes can see, seem to be running away from one another at fabulously high speeds. From this observed fact originated the famous theory of the expanding universe. Although the theory is still not finally proved, it seeded a whole generation of fruitful study not only in astronomy but also in geology, physics and chemistry. It gave us a new start for investigating the age of the universe and the creation of the stuff of which it is made. If our far-flung cosmos came originally from a dense hot core of material concentrated in one place, then we can reasonably assume that this tightly packed core must have consisted in the beginning of elementary building blocks, most of them probably neutrons, out of which all the chemical elements later were made. I shall discuss briefly some recent studies of this phase of the expanding-universe theory which have been made by Ralph Alpher, Hans Bethe and George Gamow. The main sub-

GREAT NEBULA in Andromeda is full-size galaxy closest to Milky Way. Photograph by Lick Observatory.



SPIRAL nebula in Canes Venatici is seen along a line perpendicular to its long axis. Photograph by the 60-inch reflector at Mount Wilson.

EDGE of galaxy N.G.C. 4594 in Virgo faces the Milky Way. Below: "barred" spiral N.G.C. 5850 suggests galaxy in earlier stage of formation.



ject of this article, however, is the basic theory itself, and how it stands up today, 19 years after Hubble's discovery.

The idea of stellar galaxies is a comparatively recent discovery in astronomy. The celestial shapes that we now recognize as galaxies had been observed for a long time as faint nebulosities of various regular forms, but they were generally believed to be simply luminous clouds of gas floating in the spaces between the stars of the Milky Way. Observations with more powerful telescopes, however, resolved these "nebulosities" and showed that they were not clouds but huge collections of extremely faint stars. These giant stellar aggregates were far beyond the outer limits of our own stellar system, the Milky Way; in fact, it soon became clear that they formed systems very similar in shape and structure to the Milky Way galaxy itself.

The nearest and most familiar external galaxy is the great nebula in Andromeda, which can be seen with the naked eye as a faint, spindle-shaped speck of light in the upper part (from the Northern Hemisphere) of the constellation of Andromeda. Photographs made with large telescopes show that this galaxy has a rather complicated structure consisting of an elliptical center, or "galactic nucleus," and "spiral arms" flung into the surrounding space from the central body. The photographs also show two nearly spherical nebulosities close by, probably satellites of the central system.

Among the myriads of stars in the arms of the Andromeda Nebula are many pulsating ones, of the type called Cepheid variables. They brighten and fade in a regular rhythm, and their pulsation period provides a method of determining their absolute brightness. By comparing their apparent brightness (which depends on their distance from us) with their calculated absolute brightness, Hubble was able to prove that the Andromeda Nebula is some 680,000 light-years from the Milky Way. To a hypothetical observer in the Andromeda galaxy, the Milky Way would look much the same as the Andromeda system looks to us, except that the spiral arms of the Milky Way are somewhat more open. Our sun, with its family of planets, would be seen through a telescope within the Andromeda Nebula as a rather faint star near the end of one of the spiral arms, some 30,000 light-years from the Milky Way center.

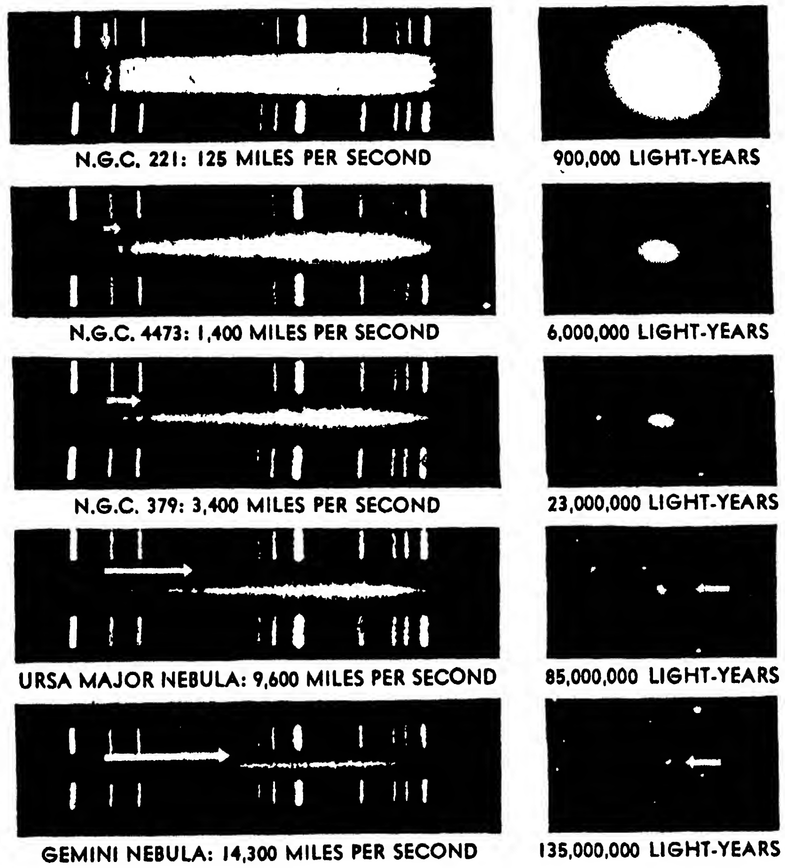
THE GALAXIES generally are shaped like a discus. The Andromeda system looks like an elongated spindle to us because it is tilted to our line of sight, but there are many other galaxies that we see from the top or straight on edge. Most galaxies have the same sort of spiral arms as the Milky Way and Andromeda, but there are also some armless ones. Individual stars are much more difficult to distinguish in armless galaxies and in the nuclei of spiral ones than in the spiral arms. It was only several years ago that Walter Baade of the Mount Wilson Observatory succeeded in resolving these interior stars by using special photographic plates and carrying out the exposures with great care. His pictures revealed an unexpected fact: the stars forming the nuclear regions of spiral galaxies, and all stars of the armless galaxies, have very different physical characteristics from those in the spiral arms. The meaning of this difference in stellar population is not clear, but there is no doubt that it has an extremely important bearing on stellar and galactic evolution.

The galaxies are scattered more or less uniformly through space as far as our telescopes can probe. The average distance between neighboring nebulae is about two million light-years. The limit of our vision with the 100-inch telescope, the largest with which observations have yet been made, is about 500 million light-years. Hence in the observable region of space there are some 100 million galaxies. The new 200-inch telescope on Mount Palomar, which will double the distance we can see into space, may reveal an enormously larger number. Most galaxies are isolationist, dwelling in remote and solitary splendor, but we find a number that group themselves together to form more or less compact clusters. In the constellation of Corona Borealis, for example, there is a cluster containing some 400 galaxies. Our Milky Way is a member of a small cluster which embraces, among others, the Andromeda Nebula and the two galaxies known as the Magellanic Clouds, which are of a relatively rare type that has no well-defined shape.

The distances of all but the nearest galaxies are so great that even the most powerful telescopes fail to resolve them into individual stars. Astronomers' calculations of their distances depend entirely on their apparent brightness. Hubble, studying a group of about 100 well-known neighboring galaxies, established the fact that on the average they were of about the same size and the same intrinsic luminosity. Using this standard, we can estimate the distances of remote groups of galaxies by comparing their mean apparent brightness with that of nearby galaxies whose distances are known. Such measurements give the value of 7.5 million light-years for the distance of one of the nearest groups of galaxies in Virgo. Similar galactic groups in the constellations of Coma Berenices, Corona Borealis and Boötes are respectively 30 million, 100 million and 180 million light-years away.

NOW WHAT was it that gave Hubble the notion that the galaxies are running away from one another and that the universe is expanding? His basic discovery was made with that indispensable tool of the astronomer, the spectrograph, which analyzes the color components of

the light coming from stars. Studying the spectra of distant galaxies, he noticed a curious fact: all the lines in their spectra, regardless of the wavelength or color of the line, were displaced toward the red end of the spectrum. Furthermore, the amount of this "red shift" was always directly proportional to the distance of the galaxy from us. The most natural explanation of this shift was that the source of the light was moving away. This is the so-called Doppler effect, of which the classic and most familiar example is the change in pitch of a locomotive whistle as the train approaches us and then speeds away. A light wave, like a sound wave, appears to shift to a longer wavelength when it reaches us from a receding source. And the speed with which the source is moving away is directly proportional to the shift in wavelength. Since the red shift of the galaxies also varied as their distance from us, Hubble concluded that the speed of the receding stars was proportional to their distance; the farther away they moved from one another, the faster they traveled. The red shift of the most distant galaxies that have thus far been observed is 13 per cent, which suggests that they are receding from us at the terrific velocity of 25,000 miles per second.



RED SHIFT of various galaxies is illustrated by comparing their spectra with that of helium (*above and below each nebular spectrum*). Shift is demonstrated by length of arrows pointing to spectral lines of calcium. Letters N.G.C. before galaxies stand for New General Catalogue.

You must not conclude from this that we stand at the center of the universe and that all the rest of it is running away from us. Picture a slowly inflated rubber balloon with a large number of dots painted on its surface. An observer on one of the spots would be under the impression that the other dots were racing away from him in all directions, and so indeed they would be, but the same thing would be true no matter which dot he was on. In the case of the galaxies, we are dealing with the effect of a uniform expansion throughout all of space.

If you pick an arbitrary point in space, say the earth, and divide the distance of a given galaxy by its recession velocity, you get a figure which represents the length of time that the galaxy has been receding from that point. The strange and wonderful consequence of Hubble's observations is that the figure will be the same no matter what pair of galaxies you pick. Thus it works out that at a fixed, calculable time in the past all the galaxies now so widely scattered were packed tightly together in one place. And the time figure you arrive at is the age of the universe, measured from that instant when the original condensed lump of universal matter was torn apart by the primordial "explosion" that started its headlong expansion.

To get this figure, we must know the exact values for the distances and the recession velocities of distant galaxies. This is less simple than it sounds. The velocities, as we have seen, can be computed from the observed red shift, and the distances, presumably, from the galaxies' apparent brightness. But there is a catch: the apparent brightness of the stars is affected not only by their distance but also by the fact that the light coming from them is redder, and therefore carries less energy, than if the light source were stationary. To illustrate this, suppose for a moment that you are shot at by a gangster operating a submachine gun from the back window of a speeding car. Since the vehicle is receding, the bullets move more slowly toward you than they would from a stationary gun, and they strike your bulletproof jacket with less energy. A receding light source produces exactly the same effect; its emitted light quanta strike the eye with less energy and therefore look redder than they should. An astronomer must make the same correction for the weakening of light intensity as a ballistics expert would make in estimating the muzzle speed of the bullets.

There is a further complication. If the submachine gun shoots, say, one bullet per second, its bullets will strike you at longer and longer intervals as the gun recedes, for each successive bullet will have farther to travel. Similarly, light quanta from receding stars enter the observer's eye with less frequency, and this fact calls for another correction of the observed brightness.

Applying both corrections, and taking the most accurate possible observations, Hubble calculated that the universe began to expand less than one billion years ago. This result stands in contradiction to geological evidence, which indicates that the age of the solid earth crust, estimated quite reliably from radioactive decay in the rocks, must be at least two billion years. Since numerous pieces of evidence in various sciences support the two billion-year estimate, Hubble was forced to reconsider the expansion theory and consider the possibility that the red shift was due not to the normal Doppler effect but to some unknown physical factor which caused light to lose part of its energy during its long trip through intergalactic space.

Such a conclusion would ruin many beautiful scientific developments that have flowed from the hypothesis of the expanding universe. It would confront physicists with the difficult task of explaining the red shift in non-Dopplerian terms—which would seem to contradict everything we know at present about light. Fortunately, there is a simple way out of the dilemma which is usually overlooked by the proponents of the "stop-the-expansion" point of view. The point is that Hubble's method of estimating the distances

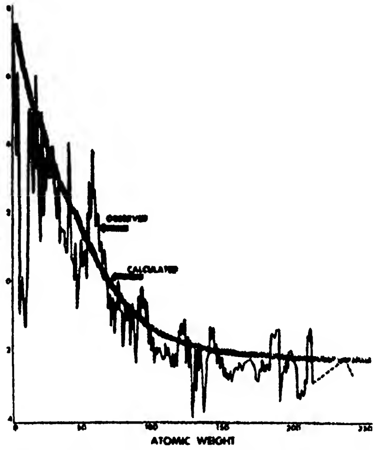
of faraway galaxies assumes that at the moment when they emitted their light they were just as bright as the galaxies we see closer at hand. It must be remembered. however, that the light we see from the distant galaxies was emitted at a fantastically distant time in the past; the light now coming to us from the Coma Berenices cluster, for example, started on its way some 40 million years ago, and the most distant galaxies used by Hubble in his studies are seen as they were almost half a billion years ago!

Do we have the right to assume that the galaxies, which are evolving like everything else in the universe, have kept their luminosity constant over such long periods of time? In view of the known facts about the evolutionary life of individual stars, which maintain their luminosity by the expenditure of nuclear energy, such an assumption would be very strange indeed. Actually, we can remove the entire difficulty in Hubble's time scale by remembering that the nuclear processes that fuel the stars are not endlessly self-perpetuating but are accompanied by a gradual dissipation of the originally available energy. The assumption that an average galaxy loses a mere five per cent of its luminosity in the course of 500 million years would bring the age of the universe to the two billion-year figure demanded by other astronomical, geological and physical evidence.

THIS CONCLUSION finds strong confirmation in recent work by Joel Stebbins and A. E. Whitford at the Mount Wilson Observatory, who have studied the apparent luminosities of distant galaxies on special plates sensitive to red light. To everyone's surprise, they found these galaxies much brighter in the red part of the spectrum than they had previously appeared to be on ordinary photographic plates, which are sensitive mostly to the blue rays. It looked at first as if this phenomenon was due to the same kind of optical scattering which makes the sun look red during dust storms: light from the galaxies, it was thought, was reddened by the clouds of fine intergalactic dust through which it passed. Calculations showed, however, that to account for the observed reddening would take a fantastic quantity of dust—100 times as much as the total amount of matter in the galaxies themselves. Such an assumption would come into serious conflict with many facts and theories about the structure of the universe.

It therefore seems more reasonable to suppose that the distant galaxies look redder simply because they actually were redder when they emitted the light which is now reaching our telescopes. This could be explained if we assumed that young galaxies contain more red stars than more mature ones. Further studies by Stebbins and Whitford should yield important information about the evolutionary life of individual galaxies. Already they have demonstrated quite clearly the danger of building any conclusions on the hypothesis of constancy of galactic brightness.

Having made this fiery defense of the right of our universe to expand, let us consider the physical consequence of the expansion theory suggested at the beginning of this article. What physical process was responsible for the present relative quantities of the various chemical elements that make up the universe? Why,



ELEMENTS are distributed in relative amounts according to their atomic weight. Author's theory coincides with elements observed in stars.

for example, are oxygen, iron and silicon so abundant; and gold, silver and mercury so rare?

We know that, except for the lightest elements (such as hydrogen, helium, nitrogen and carbon, involved in the sun's nuclear cycle), transformation of one atomic nucleus into another requires tremendous temperatures such as do not exist at the present time even in the hot interiors of the stars. Consequently there can not have been any revolutionary change in the relative abundance of the various elements since the expansion of the universe began. On the other hand, there has been some change, for a number of atoms are radioactive and have gradually decayed into more stable elements.

Considering the latter case first, we note, for example, that the lighter isotope of uranium, U-235 (atomic bomb stuff), constitutes only .7 per cent of a given amount of uranium found in nature; the rest is the heavier isotope U-238. The half-life of U-235 is only .7 billion years, while that of U-238 is 4.5 billion years. If we make the reasonable assumption that at the original formation of the universe both isotopes were produced in about equal amounts, the age of the universe figures up to about four billion years. Similar calculations based on the naturally radioactive isotope of potassium (relative abundance—.01 per cent; half-life—.4 billion years) yields the figure of 1.6 billion years. While there is a discrepancy, both figures agree roughly in order of magnitude with the age of the universe as estimated from the red shift and other evidence. Thus we have fairly good reason to suppose that the radioactive elements were formed at the beginning of the universe.

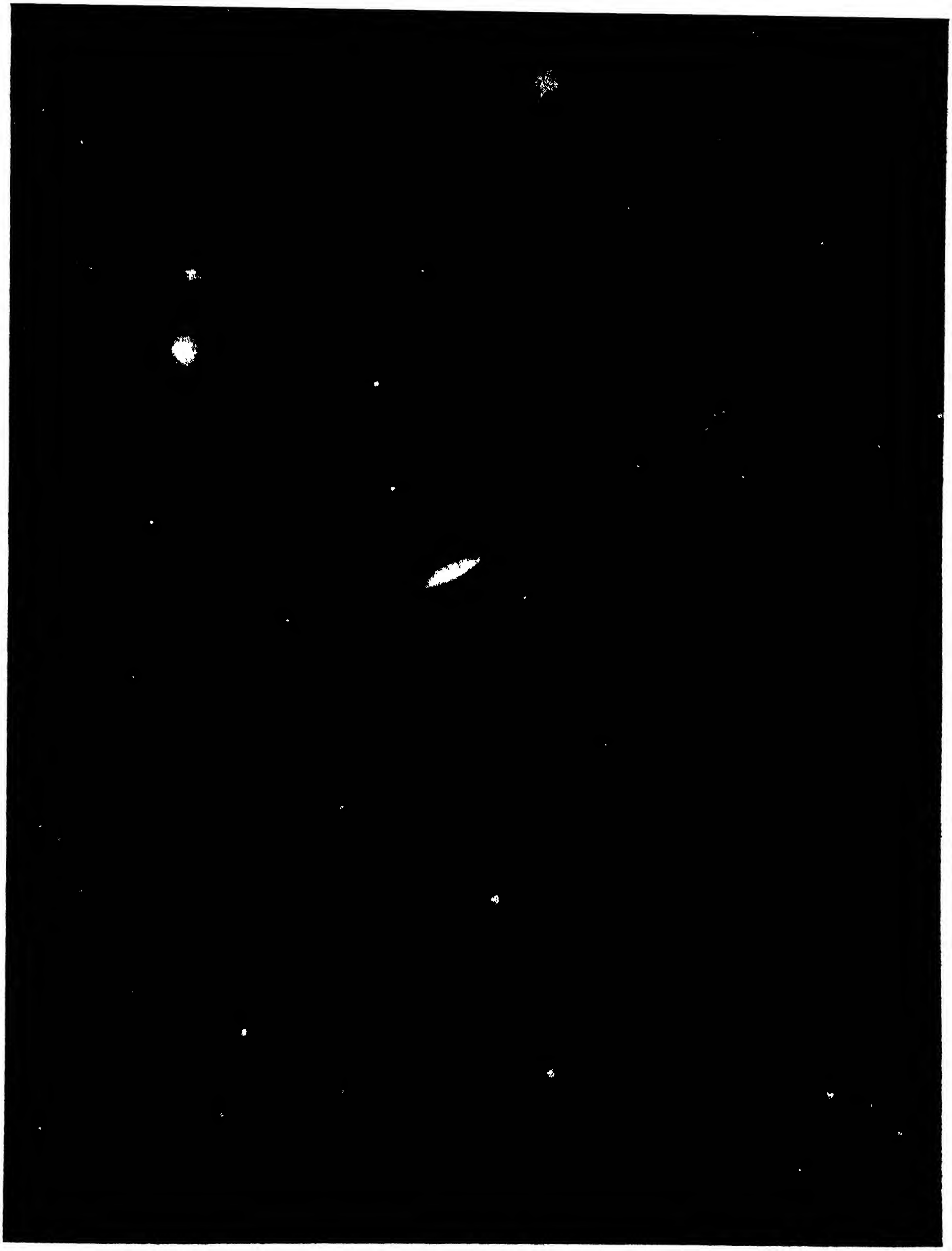
Actually, the picture presented by the expanding universe theory, which assumes that in its original state all matter was squeezed together in one solid mass of extremely high density and temperature, gives us exactly the right conditions for building up all the known elements in the periodic system. As I have mentioned, Alpher, Bethe and Gamow have attempted to reconstruct in some detail the processes by which the various elements may have been created during the early evolutionary stages of the expanding universe.

OUR STUDIES indicate that, under the tremendous temperatures and densities prevailing in the nucleus of the universe during the stage of its maximum contraction, primordial matter must have consisted entirely of free neutrons moving much too fast to stick together and form stable nuclei. As the universe started to expand, this primordial gas began to cool. When its temperature dropped to about one billion degrees, neutron condensation began. The neutrons collected in aggregates of varying numbers of particles. It is known that neutron aggregates are intrinsically unstable unless about half of their particles carry a positive electric charge. Hence they must have emitted electrons until they achieved a state of electrical equilibrium. The electrons fell into orbits around the nuclei and formed electronic envelopes around them; thus atoms were created.

I shall not attempt here to go into a detailed description of the rather involved mathematical theory of atom-building, but shall simply present a graph which compares the abundance curves of the chemical elements as observed and as calculated by our theory. The theoretical curve corresponds pretty well with the observed values; the fluctuations of the empirical curve are due to minor periodic variations of nuclear properties and can be explained by a more detailed form of the theory.

According to our calculations, the formation of elements must have started five minutes after the maximum compression of the universe. It was fully accomplished, in all essentials, about 10 minutes later. By that time the density of matter had dropped below the minimum necessary for nuclear-building processes. All the elements were created in that critical 10 minutes, and their relative abundance in the universe has remained essentially constant throughout the two or three billion years of subsequent expansion.

George Gamow, professor of physics at George Washington University, is author of Birth and Death of the Sun *and other popular scientific books.*



FOUR GALAXIES of different types recede from the Milky Way in a mighty company. They are N.G.C. 3185, N.G.C. 3187, N.G.C. 3190 and N.G.C. 3193. The evidence that these aggregates are in the same cluster is that the galaxies have the same average size and intrinsic luminosity. Groupings of galaxies are not uncommon. The Milky Way galaxy and the Andromeda Nebula, plus several smaller aggregates, form a system of their own.

ALLERGY: A DEFINITION

The original meaning of the word has been obscured by the unpleasant reactions associated with it. Without allergy, in fact, the human species could not survive

by Bela Schick

THE TERM allergy, which came into our language less than 50 years ago, has everywhere been adopted with amazing alacrity. It is now a household word, yet few persons know its true meaning. Laymen and even physicians often use the term as if it applied only to asthma, hay fever, eczema, hives and related conditions. This is a misconception. The term has much wider meaning. We are well acquainted with the allergies that make us miserable, but what we do not realize is that allergy is one of our chief defenses against fatal diseases. Without allergy the human race could not long survive.

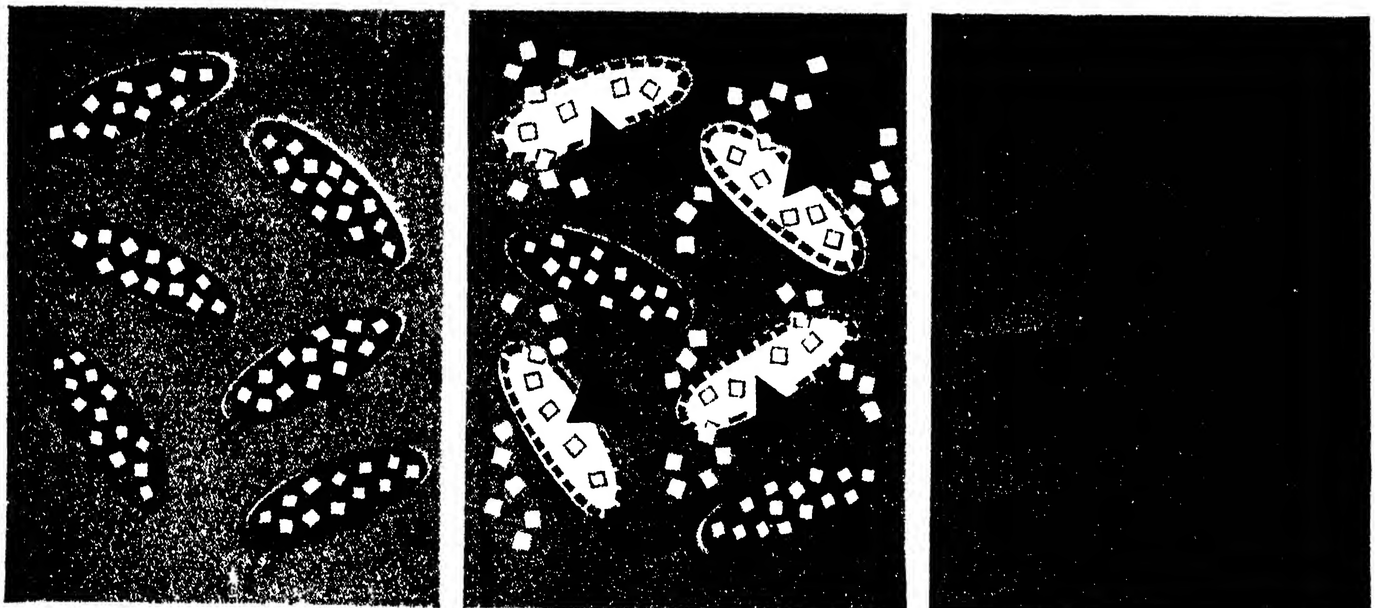
The fundamental meaning of the term can be easily explained and readily understood. It comes from two Greek words, *allos*, meaning different or altered, and *ergeia*, meaning work or, in its biological usage, reaction. It signifies simply that when the human organism is exposed to the same germ or foreign substance more than once, it reacts differently to the second dose than it does to the first.

It was Clemens von Pirquet, professor of children's diseases at the University of Vienna, who coined the word and did the original research in this subject. His allergy concept grew out of studies which he began in 1902 of the incubation period in diseases. As everyone knows, a person exposed to infection by a germ does not get sick immediately. It takes several days at least for the first symptoms of the disease to appear—this is the so-called incubation period. Why does it take so long? One explanation, it was discovered, is that the invading germ at first multiplies without inhibition, continuously producing a toxic secretion, and the disease begins to show symptoms only after the toxin accumulates in sufficient quantity. The classic example of such a disease is diphtheria. It has a relatively short incubation period.

There are other diseases, such as typhoid fever, measles and smallpox, which have a considerably longer incubation; every experienced mother knows that it takes about 14 days after exposure for a child to come down with measles. The manner in which these diseases develop must be different from that in diphtheria. The usual and most plausible explanation is this: the invading germ does not excrete a toxin, but it does multiply copiously and without hindrance within our system. If this process were not eventually checked, the result would be fatal. The germ or virus would multiply so enthusiastically that it would fill up our blood vessels and finally obstruct our circulation.

Fortunately our system is equipped with defenses that are called into play before multiplication goes too far. The invading germs stimulate the body to produce antibodies which destroy the germs. The destruction process liberates toxic substances called endotoxin within the germs. It is these toxic substances that produce the symptoms of disease. We must pay with disease to free ourselves from the invading germ. Indeed, if the invasion and multiplication of germs is very intensive, the antibodies may liberate so much poison that the patient dies a kind of involuntary suicide. But invasions of such severity are exceptional, and in some diseases we can mitigate their intensity by the use of modern drugs—the sulfas, penicillin, streptomycin—which help the antibodies by retarding the multiplication of germs.

In measles, typhoid and smallpox, the



INCUBATION PERIOD of diseases such as measles, typhoid and smallpox is explained by series of events in these three drawings. In first drawing germs that have invaded the body multiply unhindered. In second body has manufactured antibodies (*triangles*) that attack germs. The germs then liberate endotoxin (*small squares*), which causes symptoms of disease. In third drawing germs have been destroyed by antibodies. These, or at least the ability to produce them, remain as defense against the later incursion of the same germs.

incubation period represents the time required by the body to mobilize the antibodies. In diphtheria, as we have seen, incubation is the period during which toxin accumulates to the point of producing symptoms. But Pirquet observed a disease to which neither of these explanations of the incubation time applied. This is the disease known as serum sickness. It develops after the classic treatment of diphtheria with horse serum. The serum is derived from horses which have been injected with the toxin of the diphtheria bacillus. The horses then produce an antitoxin against this toxin. When their antitoxic serum is injected in a child suffering from diphtheria, it neutralizes the toxin in the child's system. Soon after the discovery of the serum in 1894, it was observed that eight to twelve days after it was injected in children they broke out with hives and fever. This was puzzling. The liquid serum itself is not toxic, as proved by the fact that even if 100 to 200 cubic centimeters is injected it produces no immediate effects; the serum sickness does not start until eight to twelve days afterward. There is no germ in the serum which could multiply or produce toxin, or release an endotoxin. What, then, is the cause of serum sickness, and why is its appearance delayed?

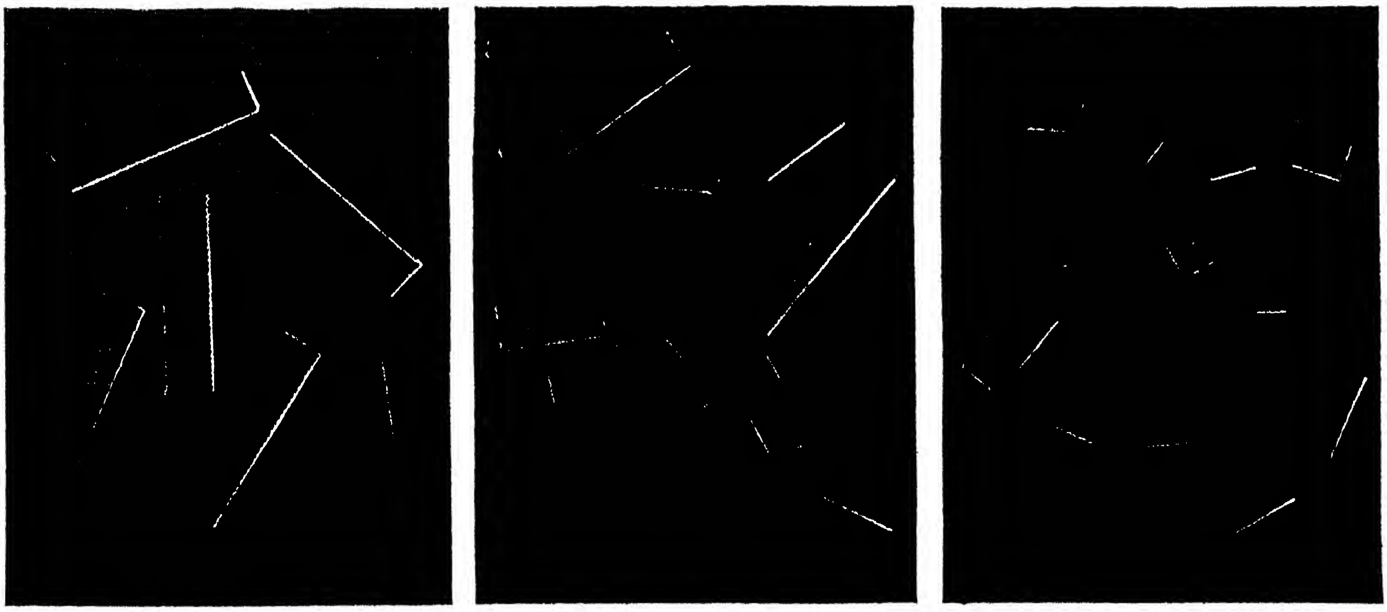
TO FIND the answer to this question, Pirquet carefully observed a child who had been treated with the serum. After the usual incubation time, the child developed hives and other familiar symptoms of serum sickness. Three weeks later this child required a second injection of serum. To Pirquet's surprise, the child came down with serum sickness within a few hours. In other words, the incubation period had been eliminated! What had happened? The serum injected was the same. There were no germs in the serum, so the second injection did not produce a cumulative effect. There could be only one explanation: the difference must be in the reaction of the child. The first injection had somehow altered the child's reaction time. It had developed what Pirquet called an "allergy."

Pirquet and I, collaborating in further studies of this phenomenon, found that if the second injection of serum was made four months or more after the first, instead of only a few weeks afterward, there was still another reaction. This time serum sickness developed not within a few hours but after four to six days. The incubation period was not eliminated but shortened. To explain this allergy or altered reactivity, we formulated this theory:

Serum sickness is due to the foreign protein (from the horse) which is present in the serum. The human system cannot tolerate a foreign protein and therefore the protein must be destroyed. It is true, to be sure, that at every meal we take in food containing foreign proteins. But these proteins must be digested before they replace our own protein destroyed daily by life processes. The digestive juices in the stomach and intestines break down the complicated foreign protein molecule to its simplest elements—amino acids. During this breakdown process, intermediate substances are formed which are toxic. But they do us no damage because they are fully converted to the safe amino acids before they leave the digestive system.

When a foreign protein is injected under the skin or into a vein, however, the protective action of the gastrointestinal canal is by-passed. The cells of the organism are capable of producing digestive substances (such as fermentlike antibodies) which break down the protein. But the toxic intermediate products that are created during this process are in position to attack the body directly, and so these poisons produce sickness, that is, serum sickness. We postulated, therefore, that the interaction between the antibodies and the foreign protein was the cause of the sickness.

At the time of the first injection of horse serum into a patient, no such antibodies are present; they must be created. This process takes time, which accounts for the incubation period. After the patient has recovered from serum sickness, the antibodies are still present, and they remain in the circulation for about four months. If the patient gets a second injection during this period, there is no waiting for antibodies to be produced; they are already on hand and attack the foreign protein immediately. Within a few minutes to a few hours the toxic intermediates appear in the blood and the patient begins to show symptoms of the serum disease. Suppose, on the other hand, that the second injection is given after a lapse of four months. By that time the antibodies have disappeared. Nevertheless, the cells appear to remember how to produce them, and this time the production of antibodies is much faster than after the first injection. Consequently the attack on the protein is accelerated and the patient's reaction also is accelerated. He shows the symptoms of serum sickness in four to six days instead of eight to twelve. These studies led us to an important corollary conclusion: if a person shows an immediate or accelerated reaction to a serum injection, one is justified in assuming that



SERUM SICKNESS sometimes occurs when patient is injected with diphtheria serum. The sickness is caused by a foreign protein in the blood of horses which have been injected with diphtheria germs to produce the serum. In the first drawing the foreign proteins have entered the body of the patient. In second drawing proteins are broken down by digestive substances into toxic products which cause the symptoms of sickness. In the third drawing these toxic intermediates have been further broken down into various harmless amino acids.

very likely he has previously been treated with horse serum.

CAN the allergy theory be applied also to the other group of diseases we considered—measles, typhoid, smallpox, smallpox vaccination? It can indeed. As we observed, when germs of these diseases invade the body, antibodies are formed to fight them. After the germs have been mastered, the antibodies continue to circulate in the blood stream for a time. If a second invasion by the same germs occurs, the antibodies kill them immediately, before they have time to multiply. Since very little endotoxin is set free, the individual has no symptoms. He is, in fact, immune to the disease. He is immune because his reaction has been altered and takes place immediately. In other words, his immunity is based upon allergy.

As in serum sickness, the antibodies in these diseases disappear in time; but they reappear more quickly in response to repeated attacks of the disease and consequently the patient has at least partial immunity. He has "shaken off the infection with very mild symptoms."

Here, then, is the principle on which medical immunization is based. To forestall a severe infection, we inoculate ourselves with a mild form of the disease by injecting a small amount of toxin, of a modified toxin called toxoid or of attenuated germs. This mobilizes an army of antibodies ready to attack any natural invasion by the same germs. Vaccination against smallpox, injections against diphtheria, tetanus (lockjaw), whooping cough and yellow fever, and BCG vaccination against tuberculosis are examples of such immunization. Their effect is to create a beneficial allergy.

Thus allergy is an essential element in man's protection against serious infections. It is also important in diagnosis. Pirquet's fundamental studies in allergy led him, for example, to the discovery of the tuberculin test. A positive result in the Pirquet test indicates the existence of a tubercular infection. By this discovery, Pirquet became the father of all skin testing. There are now a number of skin tests used in the diagnosis of various diseases.

But we must consider the unpleasant and harmful phases of allergy. They constitute only a small part of all allergy, but they do cause great misery, and in extreme cases may even endanger life. The allergies that trouble people are known as hyperallergic or anaphylactic reactions.

In our study of serum sickness, Pirquet and I found that the elimination or shortening of the incubation period was not the only result of allergy. After repeated injections, the serum disease became more intensive than in the first attack. A child became hypersensitive to the toxic substances created by the interaction between horse serum and its antibody. Occasionally, especially when serum was injected intravenously, the serum sickness was so severe that the patient went into shock and showed symptoms of asthma. Then he broke out in a violent eruption of hives. Usually the patient recovered, but in a few extreme cases he died.

At this stage of the study occurred the phenomenon so common in science—almost simultaneous discoveries in widely separated parts of the world by several groups of scientists who happened to be studying the same sort of problem at the same time. While we were investigating allergy in Vienna, the great American bacteriologist Theobald Smith was experimenting along the same lines with guinea pigs. He injected them with horse serum containing diphtheria antitoxin. To his surprise, the guinea pigs, which tolerated the first injection without ill result, suddenly died when they were given a second injection two weeks later. Their symptoms resembled asthmatic shock. At about the same time the famous French physiologist Charles Richet made a similar discovery. In a floating laboratory provided by the Prince of Monaco, he was studying a potent poison derived from a sea anemone. He injected tiny amounts of the poison in dogs. After one injection, the dogs were allowed to recover completely. They also survived a second injection given two weeks after the first. But a dog that got a second injection after an interval of three weeks died suddenly in shock. Apparently the dog had become hypersensitive. Richet called this hypersensitiveness "anaphylaxis"—from the Greek *ana*, meaning the reverse of, and *phylaxis*, protection—to denote the fact that the dog had lost a protection which it formerly possessed.

RICHET'S dog and Smith's guinea pigs quite clearly had succumbed to similar types of attack. This class of syndrome is not to be confused with a human being's repeated inoculation with disease germs, which does not produce so damaging an effect. Anaphylaxis is always serious and sometimes fatal. Evidently we were dealing here with a kind of phenomenon entirely different from a germ attack.

The hypersensitive reactions of the animals resembled asthmatic attacks in human beings. This finding focused attention on the asthma syndrome. It was found that asthma and hay-fever patients were frequently extremely sensitive to horse-serum injections. This prompted the idea that such patients should be studied from the angle of hypersensitiveness to other protein substances. Since Pirquet had already used skin-testing to determine the presence of tuberculosis, and I had used it to determine susceptibility to diphtheria, we chose this method to determine to what substances hyperallergic patients were sensitive.

It was known that some persons were sensitive to certain foods such as fish, eggs, berries and so on, and that the inhalation of pollens, especially of ragweed, could produce attacks of asthma, sneezing, swelling of the face and other symptoms. The difficulty was that this sensitivity was always strictly specific to a particular substance, and it was often difficult to identify the offending substance. The skin-test method proved to be a handy way to find the offender. Scratch tests and intracutaneous tests were performed with extracts of foodstuffs, pollen of grasses and hundreds of other substances. When a person was sensitive to a given substance, that fact was disclosed by the appearance of a wheal around the scratch or intracutaneous injection. It was found that there is almost no foodstuff which will not produce a positive skin reaction in some hypersensitive patient. From many tests we learned which substances most frequently give rise to symptoms. Those that seem to be especially obnoxious are house dust, feathers and animal emanations, particularly from cats, dogs and horses. These substances are capable of producing a great variety of unpleasant symptoms, from sneezing and coughing to outright asthmatic attacks. Some of them are: itching, eruptions of hives and other rashes, a running nose, nausea, vomiting, colics and diarrhea, migraine and other intense headaches and a multitude of similar neurological symptoms.

The allergy-producing materials are not confined to natural substances. Many materials used in industry may produce hyperallergic symptoms, often by mere contact. Chemicals (especially dyes), insecticides, cleansers, soap, and, to the distress of the ladies, such cosmetics as nail polish, lipstick and face powder may cause skin irritations. (Fortunately nonallergic cosmetics are available.) Drugs also may have hyperallergic effects. Some of the new drugs, including penicillin, streptomycin and the sulfas, have been known to cause trouble in hyperallergic patients. As a rule the drug's beneficial effect outweighs any discomfort it may cause, but in some patients its side effects may be so distressing that repeated use of the drug is inadvisable.

Protein hypersensitiveness is a heavy burden to many people. A hay fever patient, obviously, is miserable during the pollen season. Before the present treatment with injections was discovered, the patient had two alternatives: to suffer through the season or to betake himself to a place that was free of pollen. In Europe, the Island of Helgoland is such a hay fever patient's paradise; in the United States, Bethlehem in New Hampshire's White Mountains is a similarly famous haven. But nowadays a patient may be relieved without fleeing. An attempt is made to discover the specific pollen to which he is susceptible. With that knowledge he can be desensitized by means of injections of an extract of the pollen. A similar treatment with extracts

is used to reduce sensitivity to house dust, poison ivy and so on.

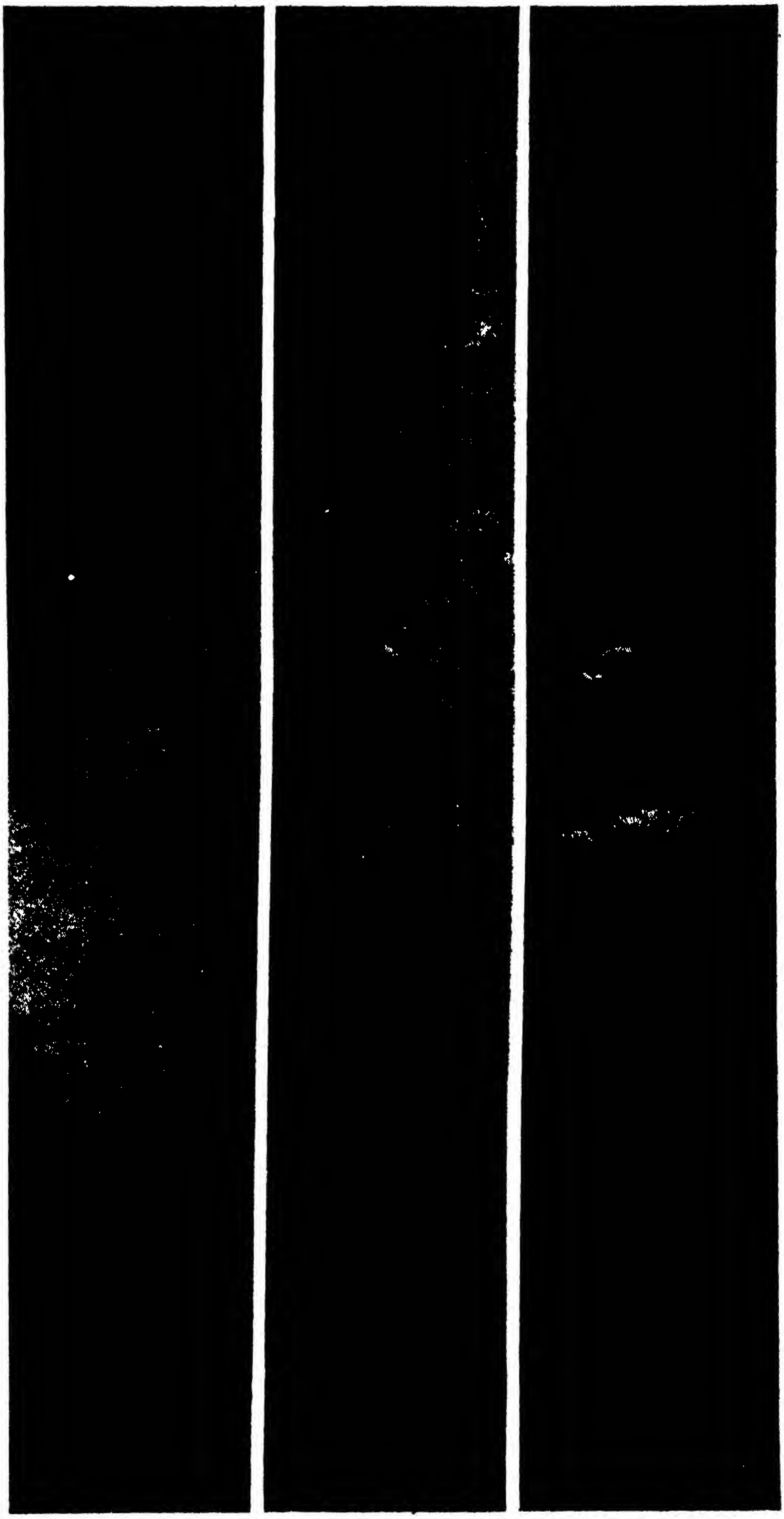
ALLERGIC reactions to foodstuffs are easier to handle. All one needs to do is to identify the offending food and then eliminate it from the diet. This may be a nuisance, but one can learn to live without eating oysters, for example, or fish, chocolate, nuts or strawberries. It is sometimes hard to keep children from food which they adore. But it has been my experience that older children are often better than adults in accepting their diet or other privations. A child deprived of the privilege of playing with dogs or cats, or riding ponies, or going to the rodeo, circus or zoo, is unhappy for a time but many children realize that it is beneficial for them to forego such pleasures.

Happily, as far as children are concerned, we can promise in many cases that their hypersensitiveness will diminish in time; eventually they become able to do all the things that other children do. One interesting discovery is that a given patient's tolerance to offending substances is not the same at all times. During periods of robust health, a hypersensitive child's tolerance may be so improved that he can eat and do everything. Again it must be borne in mind that allergy is not a disease, but only a different reactivity A hay fever patient is healthy outside of the hay fever season, and even during the season there is nothing wrong with him if he is in a locality free from pollen.

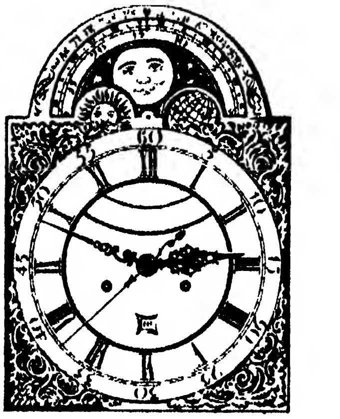
Recently a great deal has been written about the role that histamine in the body is supposed to play in the causation of hyperallergic reactions, and about antihistamine drugs. But the theory is a very debatable one and I shall not attempt to deal with it here.

In sum, then, it cannot be too strongly emphasized that the uncomfortable symptoms conjured up in the layman's mind by the term allergy are but a small part of a larger whole. The conspicuously annoying effects of these allergies project them so disagreeably and intensely into our daily lives that the much more comprehensive and beneficial implications of allergy are generally overlooked. Actually allergy is a great boon to mankind. Instead of focusing our displeasure upon the discomforts caused by hyperallergic reactions, we should be grateful for the immunity we gain from this marvelous process. Were it not for allergy, the germs would kill us all. As medicine progresses, it should become possible to find effective treatments for the disagreeable phases. The time will come when no one will doubt that nature has indeed been kind to have given us the blessing of allergy.

Bela Schick, originator of the Schick test for immunity to diphtheria, is consulting pediatrician at New York's Mt. Sinai Hospital.



TEST FOR ALLERGY, made by scratching patient's arm with common allergens, produces miniature allergic reaction. First picture shows scratches immediately after they were made. The second, after one minute, shows wheals about scratches made with pollen extract of grasses (*top*) and ragweed. Third, after five minutes, shows patient is most sensitive to ragweed.



SCIENCE AND THE

U. S. Joins WHO

AFTER a year of hesitation, the U.S. has become a member of the World Health Organization. Ratification of the WHO charter was voted by the Senate last July. Similar action by the House was held up, however, until early last month by the House Rules Committee, which had declined to give the ratification resolution a place on the House calendar. The ratification was signed by the President June 14, making the U.S.—last of the Big Five nations to act—WHO's 42nd member.

As finally voted by Congress, the ratification resolution contains four House-imposed limitations on American participation in WHO. First, the U.S. financial contribution is limited to $1,920,000 a year. Second, the U.S. member of WHO's executive board must be an M.D. with at least three years of active practice. Third, U.S. representatives in WHO are to be investigated for loyalty by the FBI. Fourth, the resolution contains a broad reservation with respect to U.S. acceptance of specific WHO proposals.

Ratification came just in time to permit the U.S. to send a regular delegation to the First World Health Assembly, which met in Geneva June 24 for the formal launching of WHO. Over 500 delegates and technical experts from some 70 member and non-member countries were present as WHO took over from the Interim WHO Commission established two years ago by the United Nations. The Assembly mapped programs for fighting tuberculosis, malaria and venereal disease, and for promoting maternal and child health on a global scale.

Science Foundation Fails

AMONG the measures that fell by the wayside as the 80th Congress adjourned was the National Science Foundation bill. After the Senate had passed an amended version of the compromise Foundation bill on May 5, action was begun in the House Interstate and Foreign Commerce Committee on the original version of the compromise bill. As the result of a hearing June 1, the Committee reported out a bill which was also amended in several particulars. There were still differences between the House and Senate versions and a conference to reconcile the two would have been necessary. The Rules Committee did not assign it a place on the House voting calendar. Since the 80th Congress is now over, the Senate vote goes for naught; the bill is now dead and will have to be reintroduced in both branches of the 81st Congress.

Two other bills affecting science were passed, however, just before the last-minute draft and ERP battles. The first, signed by the President June 16, creates a National Heart Institute, similar to the National Cancer Institute, within the U.S. Public Health Service to carry on research in cardiovascular-renal diseases. But no funds for the Heart Institute were appropriated. The other measure sets up a National Institute for Dental Research in the Public Health Service.

$11 Billion in Chemicals

DURING the past quarter-century the chemical-process industries have displaced steel as the nation's largest industry. In the first of a new series of annual surveys, *Industrial and Engineering Chemistry* reports that the 1947 output of chemicals and allied products had a value of $11 billion— more than one and a half times the $7.1 billion gross product of the steel industry.

Twenty-five years ago the annual output of chemicals and related products such as paints and drugs was only $3 billion. The rise since then stems almost wholly from technological and scientific advances, because many of the most important chemical products of 1947 did not exist or were merely laboratory curiosities in 1923. Synthetic yarns, synthetic rubbers, several new classes of plastics, insecticides, the sulfa drugs, penicillin, streptomycin and other new products have brought a 30-fold increase in the production of organic chemicals. A five-fold increase in the output of basic inorganic chemicals has also taken place, due partly to the rise of the organics (for which inorganic chemicals are required as raw materials) and partly to the emergence of new synthetic fertilizers. The chemical industry's growth will continue for some time, since it has expanded its research facilities along with its production. As a consequence there are more new chemical developments on the horizon today than ever before.

German Documents

FOR the second year in succession, the Senate has come to the rescue of the Office of Technical Services, the Government agency charged with analyzing and publishing captured German scientific and technical documents. Four years ago OTS was established by the Department of Commerce to provide technical assistance to small business during postwar reconversion. When hundreds of tons of captured German technical reports began arriving in the U.S., the task of processing them and making their contents available to interested American laboratories and manufacturers was added to OTS' functions. Both this year and last, however, the House of Representatives failed to appropriate funds for OTS. Only Senate appropriations have kept the agency in existence. OTS will continue for another 12 months, but its appropriation is only $200,000. Since it has been directed to wind up its work within the year, OTS will be able to do little more than list the titles in the 2,500 trunks of German papers remaining to be opened.

Cape Cod Mecca

THIS season Woods Hole, Mass., is back to its peacetime norm as a traditional summer capital of American science. On a southern extension of Cape Cod opposite historic Martha's Vineyard, Woods Hole is the home of two world-famous institutions, the Marine Biological Laboratory and the Woods Hole Oceanographic Institution. The Marine Biological Laboratory is host in July and August to scientists who come from nearly every state and from abroad to work on a wide variety of general biological problems, many of which are most conveniently studied in marine animals. This summer the Laboratory has nearly 500 researchers in residence. The Oceanographic Institution, the field of which is the physics and chemistry of the ocean, also is having a busy season.

During the war the Marine Biological Laboratory was shut down. The Oceanographic Institution operated full blast, but worked exclusively on problems of warfare at sea, such as underwater acoustics. Although the Institution still holds Navy contracts, the last naval officer has left. With 385 scientists in residence, it has resumed the study of heat exchange between the sea and the air and other basic oceanographic problems.

Senior Societies

THE most esteemed honor offered to an American scientist, aside from award of a Nobel prize, is election to the National Academy of Sciences or the American Philosophical Society. The Academy, founded during the Civil War by an act of Congress (but privately supported) to advise the Federal government on military-scientific problems, has 401 members drawn from the physical

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and biological sciences and psychology. The Philosophical Society, which dates back to colonial times, has approximately the same membership but fewer scientific members, since arts, letters and the social sciences also are represented.

At their spring meetings, the Academy elected 30 new members and the Philosophical Society 14. Among them was Gerty T. Cori, Washington University of St. Louis biochemist, who was elected to both—the fourth woman scientist to receive this dual recognition. Dr. Cori joins her husband, with whom she shared a 1947 Nobel prize for their studies in carbohydrate metabolism, in the two societies. Another elected to the Academy was Glenn T. Seaborg, discoverer of plutonium. The Philosophical Society's elections included Robert Fox Bacher, physicist member of the U.S. Atomic Energy Commission.

Hybrid Corn

EARLY this spring, the UN Food and Agriculture Organization shipped $300 worth of hybrid corn seed to 17 European and Middle Eastern countries. With this, FAO hopes to bring a new order of farming to Europe and the Middle East, for hybrid corn has increased American corn yields by more than 20 per cent in a decade and a half.

Corn has never been a popular crop outside the New World. However, experimental plantings of hybrid corn in Italy last year—the first outside the U.S.—surprised Italian farmers. Yields ranged from 32 to 117 per cent higher than the inferior varieties used most often overseas. FAO believes that hybrid corn will overcome the Old World farmer's lack of interest in corn and make a significant contribution to the world food supply by multiplying the acreage devoted to one of the most efficient food crops known.

'ERP' for Science

THREE years after the end of the war, scientific workers abroad—who include many of the world's outstanding talents—still labor under frustrating handicaps. Aside from the question of their health and personal well-being, their equipment is obsolete or worn out, or was lost during the fighting. Most of the apparatus-makers who supplied them, moreover, are either out of business or are engaged in urgent tasks of reconstruction. In many countries, the only possible source for thousands of items of laboratory supplies and equipment is the U.S.—but the countries concerned have no dollars.

Two schemes for dealing with the situation are slowly being developed. The nearer of the two to materialization is an arrangement worked out by a group of American apparatus-makers who last year formed a U.S. Scientific Export Association. Sometime this summer the Association is to receive a $2,500,000 credit from the Export-Import Bank to finance apparatus exports to countries short of dollars. Shipments will probably begin next year to countries that make necessary supplementary agreements with the Export-Import Bank. The second scheme, to provide $3 to $4 million in dollar credits for purchase of American equipment by European institutions, is a UNESCO project. UNESCO's first financing proposals were rejected by the major nations, but more acceptable suggestions are expected to come from a current UNESCO meeting in Paris. If both the American and the UNESCO plans materialize, some $6 million will become available for re-equipping research centers abroad—by no means a large sum, but a useful adjunct to other efforts.

Max Planck Society

ONE of the first acts of the Allied Control Council in Germany was dissolution of the Kaiser Wilhelm Institute, the central agency through which German scientific work was coordinated and which played an important part in German military research. German scientists wondered what was to become of the 50 research agencies that were affiliated with the Institute. A partial answer has come from the ancient university town of Göttingen in the British zone. Under the presidency of Otto Hahn, discoverer of uranium fission, 11 German Nobelists living in the bizonal area have formed the Max Planck Society for the Advancement of Science to take the place of the Kaiser Wilhelm Institute. Until private and industrial funds become available, the Society expects to obtain funds for research from the bizonal government.

Two former affiliates of the Kaiser Wilhelm Institute, the Kaiser Wilhelm Institute for Coal Research at Heidelberg and the Paul Ehrlich Institute for Vaccines at Frankfurt, have joined the Max Planck Society. Nothing has been heard, however, from institutes in the French or Soviet zones, nor have any in the British zone as yet completed affiliation.

Meetings in August

AMERICAN Institute of Electrical Engineers, Pacific general meeting, Spokane, Wash., August 24-27.

American Chemical Society, Eastern session, Washington, D. C., August 30-September 4.

PHYSICS AND MUSIC

The agreeable sound of simple melodies and Beethoven symphonies is guided by physical rules, plus a little physiology and psychology. The understanding of these principles can enhance musical creation and enjoyment

by Frederick A. Saunders

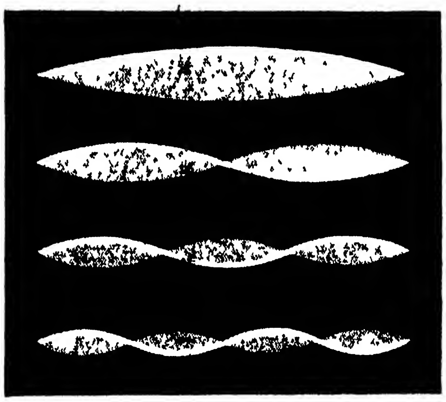
ANYONE who looks upon a great bridge arching across a wide river is thrilled by its beauty, and aware at the same time that a great deal of measuring, testing and calculating must have gone into its planning to make the structure safe. A bridge is an obvious combination of art and science. Not so obvious is the physical architecture of great music. One who listens to a symphony at an orchestral concert may know that the composer drew on his inspiration to fill pages with symbols, and that the conductor and his musicians interpret these to help bring to life again what was in the composer's mind. The listener is intellectually and emotionally moved by the sequence of sounds coming to him from many different sorts of instruments. But what has this bewilderingly complex example of art to do with science?

The answer is simple enough. Music is based on harmony, and the laws of harmony rest on physics, together with a little psychology and physiology. The simplest and most pleasant intervals of music have always existed among the harmonics of pipes and strings. From them grew the study of harmony, and they have formed the basis of many noble melodies. A classic example is the opening melody of Beethoven's *Eroica* symphony, whose first part consists of the simplest possible intervals flowing one after the other. Such simple combinations do something to our ears which is fundamentally pleasant and satisfying. Some musical instruments were well developed long before the subject of musical acoustics was born. Today the physics of music helps to guide improvements in musical instruments, in the construction of buildings with good acoustics, in the reproduction of music for immense audiences, and in many other ways.

To examine the physical basis of music we begin by considering the nature of sound. Sound is a word used in at least two senses: (1) the sensation produced in the brain by messages from the ear, and (2) the physical events outside the ear.

SYMPHONY is a vast blend of frequencies from many instruments. At left: Leopold Stokowski conducts rehearsal of New York Philharmonic.

The context usually makes it plain which meaning is intended. Thus we avoid long arguments over whether a sound can exist if there is no one present to hear it. Sound has its origin in a vibrating body, and the vibration may be *simple* or *complex*. The motion of the pendulum of a clock represents a simple vibration, one which is not rapid enough to be audible. To be heard as a musical tone, a vibration must have a frequency of at least 25 cycles per second. A pure tone is represented by a smooth



HARMONIC series is defined in various vibrations of a string. Harmonizing frequencies are two, three, four or more times simplest vibration (*top*).

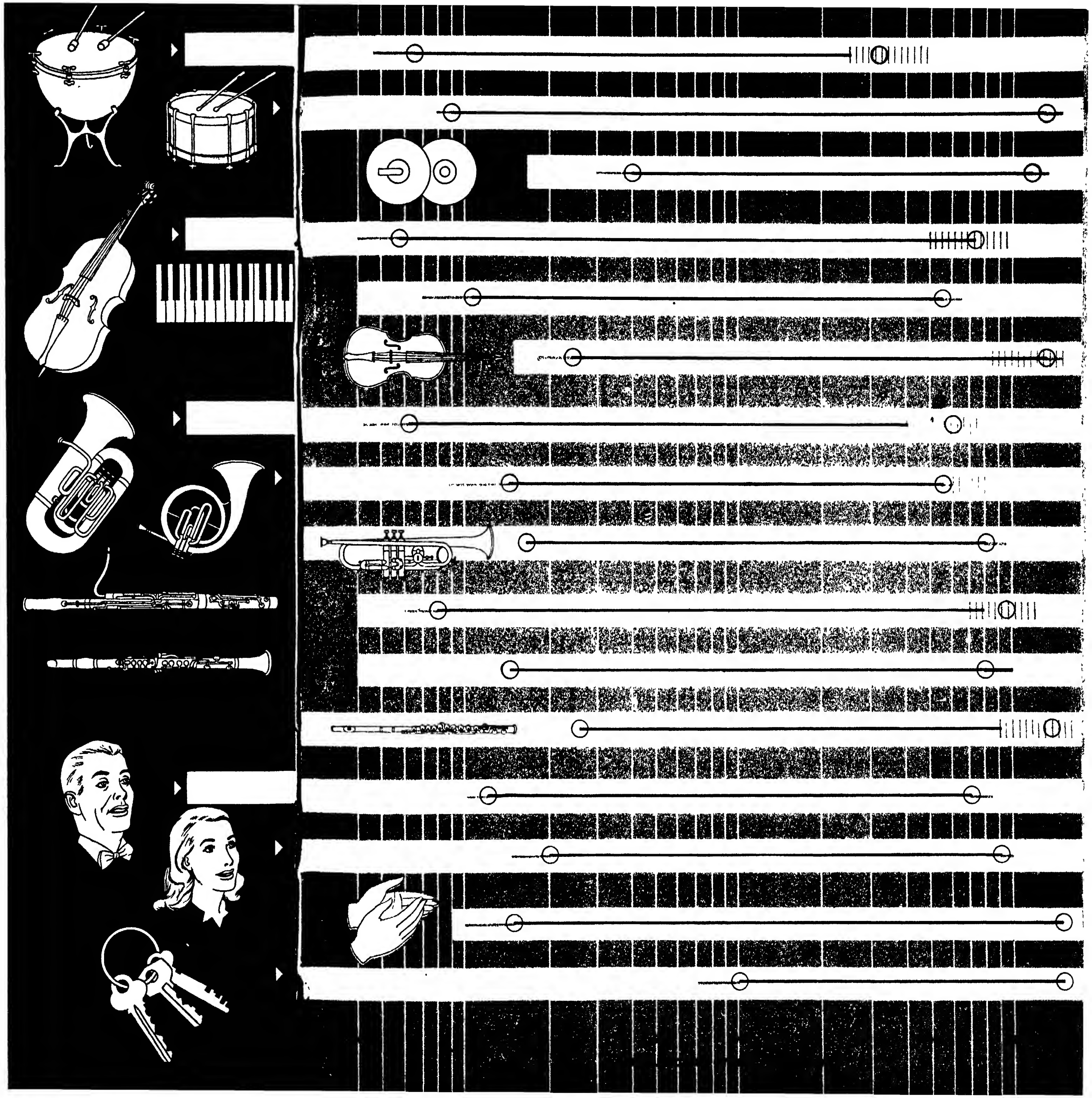
curve in which distances to the right stand for time, and distances up and down correspond to the displacement of the vibrating body from its position of rest. A vibration of this sort is often called simple periodic motion because it repeats itself regularly with a constant period of time for each repetition. But pure musical tones are rare; the tones that are produced by musical instruments are almost always complex.

Complex vibrations can always be regarded as made up of a combination of simple vibrations of different frequencies. Their forms are very varied, as shown in the illustration on page 38. Sometime when you are out walking and have nothing better to do, try swinging your arms at different rates. The simplest case is easy: right arm going at twice the rate of the left. It is not quite so simple to make the right arm alone combine both of these motions, and it is still harder to combine rates whose ratio is one to three, two to three, and so on. One gives up before long; yet any violin string can do this easily without becoming confused. It can combine as many as 20 different rates at the same time into one complex vibration, which is caused in this case by the complicated motion of the string under the bow. These frequencies are simply related; their values are proportional to the integers 1, 2, 3, 4 and so on. They form a harmonic series. The vibration with the lowest frequency, corresponding to the number 1, is called the fundamental; the sound with double this frequency is the first harmonic, and the higher harmonics are calculated in like manner.

I. Harmonic Analyzers

The scientific study of musical instruments depends partly upon the resolution of complex tones into their harmonic elements, a process called harmonic analysis. It is often of practical importance to determine what components are present in a tone and how strong each one is. One old method of analyzing a musical tone is to study its wave form, as pictured by means of a microphone, an amplifier, and a cathode-ray oscilloscope (*see cover*). But the wave is frequently very complicated, and its analysis by mathematical methods into the simple waves of which it is built is very slow and tedious. In recent years instruments have been developed which analyze complex tones automatically, yielding rapid and accurate results.

Some of these harmonic analyzers make use of the physical effect called resonance, which is a response produced in one body from the vibration of another body. It is easily demonstrated on a piano. In piano strings the harmonics are strong. If you press gently on the key an octave below middle C, so as to free the string but not to strike it, and then strike the middle C key sharply, you will hear a continuing middle C tone coming from the lower string. The experiment succeeds only if the strings are in tune. The middle C frequency (about 260 cycles per second) is



FREQUENCY RANGE of some musical instruments and other producers of sound is tabulated in chart adapted from book *The Psychology of Music*, by C. E. Seashore. Frequencies, noted in scale at the bottom of page, are plotted horizontally. Range of scale is 40 to 20,000 cycles, as compared with the human ear's approximate range of 25 to 30,000 cycles. The thin line within each light horizontal bar indicates actual range of frequencies produced by each method. Circles on each line indicate effective range estimated by a group of expert musicians. Vertical lines at the right end of each frequency line indicate range of associated noise. The instruments in black panel are, from top to bottom, tympani, snare drum, cello, piano, bass tuba, French horn, bassoon, clarinet, male speech, female speech and jingling keys. In blue panel are cymbals, violin, trumpet, flute and clapping hands.

equal to that of the first harmonic of the lower string; hence the lower one can respond.

By a variation of the experiment, one can play a chord on a single string. Hold the lower string open as before, but now give a strong impulse to three keys at once—middle C, the C above and the G between. After the upper strings have been quieted, all three tones will be heard coming from the lower string alone, which is resonating to three frequencies at once. This works as well the other way around: hold the same three upper keys open with the right hand and give the lower C a sharp blow. The three upper tones will be heard, coming from the three untouched strings. Or again, try singing a tone into a piano with the loud pedal pressed down. (This frees the strings to vibrate in resonance with any tone with which they agree in frequency.) When you stop singing, you will hear a faint mixture of tones issuing from the piano.

If we had some kind of attachment to the strings by means of which the response of each could be recorded, we should have one type of harmonic analyzer, but not a very good one. It would be unable to respond properly to frequencies lying between those of the strings. A more useful type of analyzer would be a single string whose pitch we could change slowly and steadily throughout the whole range of the musical scale. This could be fitted with an attachment which would record the string's responses, whenever they occurred, to the tone being analyzed. Such a device would be like the tuning apparatus in a radio receiver, which picks up radio waves on each frequency over which they are being broadcast. The device would miss nothing, but it would not be capable of making analyses instantaneously. The same sort of plan, carried out electrically, gives more rapid results. With suitable equipment it is possible to obtain within a few seconds a complete photographic analysis of a sustained tone, yielding numerical values for the strength and frequency of all harmonics present in the frequency range from 60 to 10,000 cycles per second. This method has been applied to the study of the tones of many instruments.

A remarkable frequency analyzer recently developed by R. K. Potter of the Bell Telephone Laboratories gives a continuous analysis of speech: its result is appropriately called "visible speech." One speaks into a microphone and the oscillations of his speech are then passed through 12 electrical filters, each of which allows only a narrow range of frequency to pass. When amplified, each filtered set of oscillations lights a tiny "grain-of-wheat" lamp; there are 12 lamps, arranged vertically. The fundamental tone of the speech lights one lamp, the first harmonic another farther up, and so on. The lamps that light in response to the speaker indicate the frequencies present in his speech. To reproduce his speech pattern, the light from the lamps falls on a horizontal moving belt made of phosphorescent material, so arranged that each lighted lamp traces a separate luminous line on the belt. The result is a characteristic pattern for each vowel and consonant, defined by lines of varying frequency and duration. The accompanying illustration demonstrates how a phrase looks to the eye. A trained observer can read words and phrases at sight, and a person who has been deaf from birth may thus learn to read speech. He can also correct imperfections in his own speech by matching the patterns he produces against standard ones. This visible speech is exciting to watch, and it is likely to be of great help to the deaf.

II. The Violin

Now let us turn to the consideration of musical instruments, a subject in which harmonic analysis has been very useful. We may agree at the start that nothing deserves the name of musical instrument unless it can make a loud sound. Our greatest musical artists must fill large concert halls, and for this they need loud voices, violins, pianos or other instruments. Some musical instruments require a method of amplifying the vibrations created by the player to produce powerful tones. Consider the violin as an example.

A wire mounted on a bent iron rod, with no body or plate to shake, gives almost no sound when it is excited by bow or finger. The wire is too narrow to push the air about sufficiently to create a strong sound wave. Such a performance is analogous to trying to push a

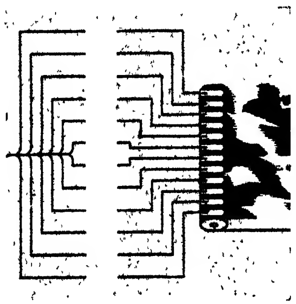
canoe through the water with a round stick as a paddle. If you stretch a piece of strong twine between two hands and pluck it with a free finger, it makes very little sound. But if a part of the twine near one end is pressed on the edge of a thin board, you have a crude stringed instrument, giving a much louder sound, which now comes from the board. The sound of a violin is emitted not from the strings or the bow but from its light wooden body. The contact between the strings and the body of a violin is through the wooden bridge, which is cleverly cut to filter the sound transmitted and remove some unpleasant squeaks. To produce loud sounds, the violin body must satisfy three conditions. It must be strong, light enough to be easily shaken, and big enough to push a lot of air around when it moves. The sounding board of a piano must fulfill exactly the same conditions.

As everyone knows, stiff objects vibrate much better than limp ones; we all have observed, for instance, how noisy a job it is to wrap a parcel in stiff paper, whereas if a handkerchief is substituted for the paper there is almost no sound. Large areas of stiff paper tend to move together as one piece, and thus push on the air sufficiently to start vigorous sound waves. In a violin, the wood must be light, so that the vibrations of the strings can move it, and strong enough to sustain the tension of the strings, which adds up to about 50 pounds. The kinds of wood most used are close-grained Norway spruce for the top plate, and maple for the back.

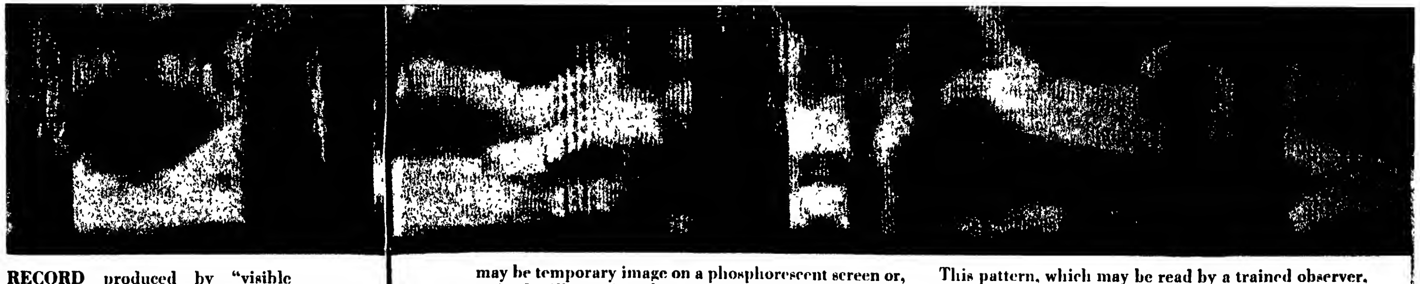
The body of a violin should respond equally to all frequencies of vibration within its range. The fact that it fails to do this is seldom noticed. The reason for the defect will be clear if we first consider the beautiful method devised by the German acoustical physicist Ernst Chladni (at about 1800) which discloses the natural modes of vibration of plates. By sprinkling sand on a flat metal plate and drawing a rosined bow across its edge, one can get a musical tone, and some of the sand is seen to move from certain areas and some to rest along quiet "nodal" lines. The accompanying illustrations show various figures produced on violin-shaped metal plates which were fixed at both ends and at a point corresponding to the violin sound post. In each figure there are several patterns, and each pattern is associated with a tone of a particular frequency. These tones are not in a harmonic series; in fact they are usually discordant with one another. A high tone forms a pattern of many small areas; a low tone produces a few larger ones. Every violin has its own natural modes of vibration, scattered over the musical scale, and eight or ten of them may be especially strong. When a violinist produces a tone coinciding with a strong natural frequency of his instrument the violin responds loudly, but if he makes one in the range between two such frequencies, the response is poor. This unevenness in response occurs in the playing of the best artists on the best violins, but it is seldom noticed since no artist is expected to maintain an even loudness.

The number of harmonics produced, and their strength, determine the "tone color" or timbre of a sustained tone from a violin. Whenever one of the harmonics comes near one of the natural vibrations of the plates, it is increased in loudness, and the tone is changed in tone color. This happens often, because there are several natural vibrations and many harmonics in each tone. Thus the tone color varies throughout the range of the violin. No one tone color is characteristic of any violin—much less of violins of any particular age or from any one country.

As a machine for producing sound a violin is very inefficient. Most of the work done by the player in rubbing the bow against the strings is lost as heat in the wood. The Chladni patterns show another reason for inefficiency. Two adjacent areas in a plate must be moving in opposite directions when the plate vibrates, rocking back and forth with the separating nodal line at rest between them. Thus at the same instant the air is compressed by one area and expanded by the other. The net effect on the air is greatly reduced, since the contributions of the two areas nearly cancel each other. Moreover, the front and back surfaces of any plate may work against each other: while one surface compresses the air, the back of the same area starts an opposite expansion. If the two waves can meet at the edge of the plate they will partly destroy each other. This action weakens the low tones particularly, not only in violins but in pianos and loud-speakers. To prevent this effect in loud-speakers, the vibrating area is commonly set into a "baffle" which, by enlarging the surface, inhibits the meeting of the front and back waves. Larger vibrating surfaces can emit low tones better. This is why the violoncello and double bass are made progressively bigger, and why the large sounding board in a concert grand piano helps to improve its deep bass tones.



ANALYZER made by Bell Laboratories separates sound frequencies with 12 filters. Each regulates a tiny light. Lights make image on screen.



RECORD produced by "visible speech" apparatus depicted at left may be temporary image on a phosphorescent screen or, as in the illustration above, a pattern on a paper strip. This pattern, which may be read by a trained observer, represents phrase "Four score and seven years ago . . ."

Not all of the tone emitted by a violin is produced by vibration of its plates. We must also credit the air inside the box with an important contribution. This air can vibrate in and out of the *f*-holes with a frequency which lies in the middle of the lowest octave. The tone there would be mean and ugly without the added vibration of the inner air, as one can discover by plugging the *f*-holes lightly with cotton. When the air inside the box is vibrating at or near its natural frequency, its resonance is strong. This can be demonstrated by setting a candle in front of one of the holes, with the instrument held vertical. When the right note is bowed, the flame dances wildly; for all others it remains quiet. (The effect is most marked in a cello.) Air resonance improves the tone just where improvement is most needed; that is, over a few semitones where the small size of the violin prevents the body from emitting the tones strongly. The maximum effect is near C sharp on the G string in violins, and near A or B on the G string in violas and cellos.

III. Old v. New Instruments

Now what makes a superlative violin? This question is endlessly debated, but it cannot be settled by arguments. The most accurate and careful measurements in a laboratory with modern equipment are required, and a start has already been made. The impression made by a violin on a listener is due to many features: the quality or "tone color" of sustained tones, the ease with which the tones begin, the rate of decay of the sound, the loudness in different parts of the range. These items are often lumped together under the word "tone"; here we must separate them carefully. The tone color of sustained tones is probably the least important of the lot. The loudness in different ranges of pitch may be the most vital consideration in the judgment of a violin. A bad violin is weak in the low tones and too strong in the squeaky top frequencies.

Old violins are almost always thought to be better than new ones, and European better than American. This opinion may come in part from psychological causes—our admiration of old civilizations, the influence of tradition and so on—but part of it certainly comes from the beauty of workmanship characteristic of the best old instruments, and from their rarity. It is as difficult for most violinists to find any defect in a Stradivarius as it is easy for them to criticize the best-made American violin. In recent years careful experiments have been made with excellent modern apparatus, seeking to measure all the mechanical features mentioned in the preceding paragraph. A great variation in values was found among 12 Strads, many other old violins and a few dozen new ones, but the average values failed to show any consistent difference between old and new. This is not to say that there are no differences, but that the results were the same within the limits of error in the measurements, using very sensitive methods. These bold statements are supported by many "blindfold" audience tests, as well as by variations in professional opinions as to the merits of certain famous violins.

Violins seem to become lighter and better when played for a century or two. The effect of age on instruments which are not played appears to be small. Changes in the physical character of a violin can come about through vibration and also from contact with players. After a period of use a violin usually weighs more because it has absorbed water vapor from the air around the player. This makes the wood expand across the grain; when not in use it dries out again and contracts. These changes may alter both the physical and chemical properties of the wood. Some day it may be possible to attain the effects of years by a quick treatment of the wood; promising work along this line is now in progress.

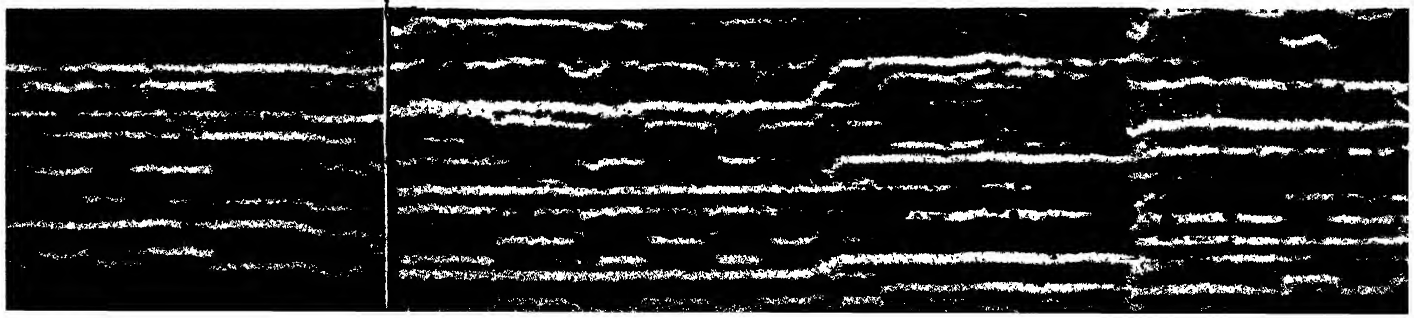
There are methods of mapping out the natural vibrations of a violin by exciting it electrically and measuring its response at every frequency. This yields a curve, called the response curve, by means of which violins can be compared. The inequalities in response at various frequencies are remarkable, in both old and new instruments. All good violins should in the future have a certified response curve furnished with them when they are offered for sale.

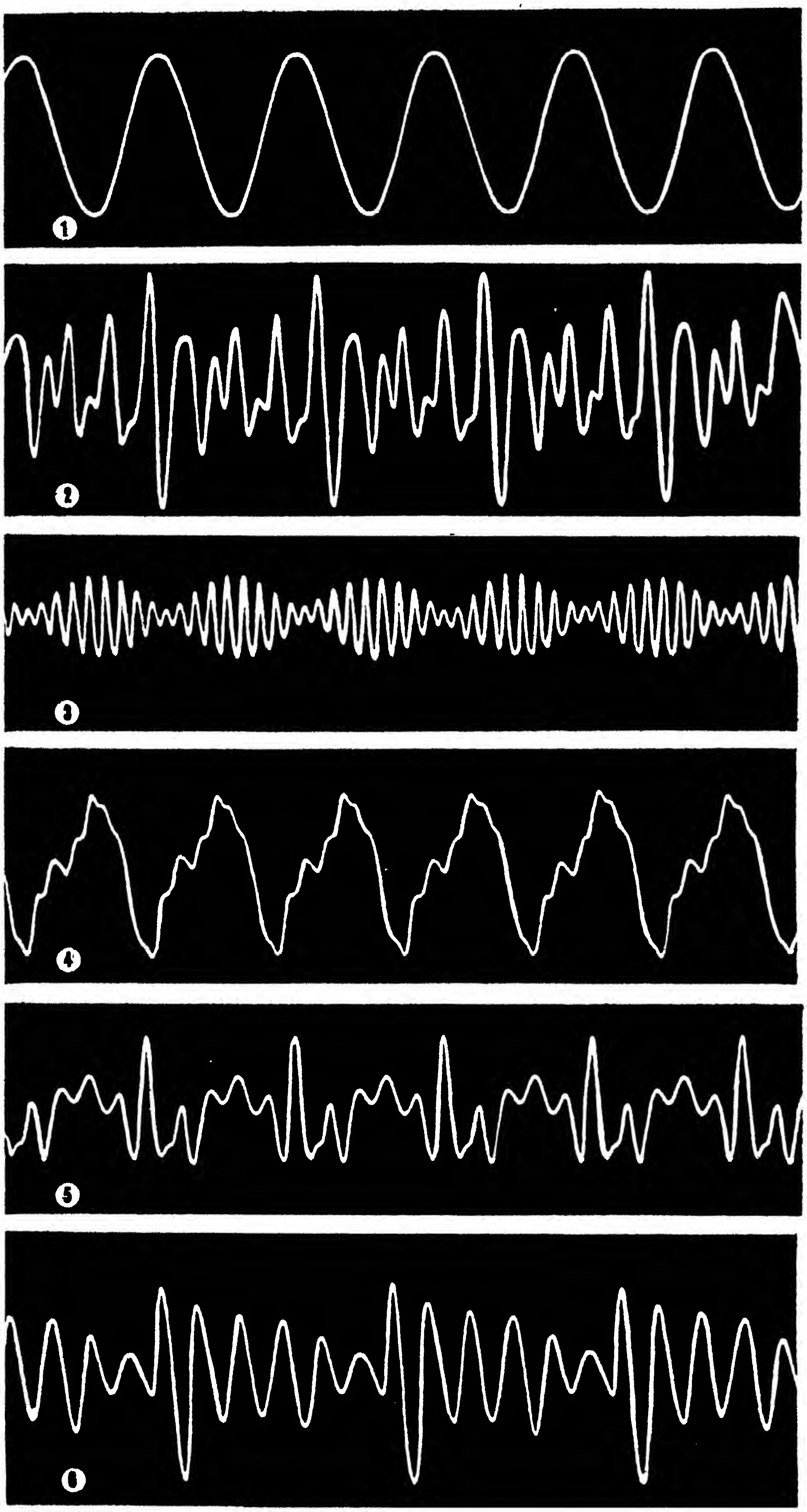
IV. The Piano

Some of the statements which I have made about the violin apply equally to the piano. The piano's sounding board acts like the violin body. While the violin has not changed in the last century, the piano has seen constant improvements in the sounding board, the strings, the hammers and the key action. So loud has the instrument become that the vibrations now shake the floor and are sometimes transmitted through the solid structure of a building to unexpected distances. In apartment houses peace may sometimes be preserved with the neighbors by placing rubber pads between the piano legs and the floor.

New problems arose with the invention of the piano's key and hammer mechanism. The hammer must be light but strong, in order to act quickly and give powerful blows to the strings. The pads must be soft to avoid the production of strong high harmonics that a hard hammer creates. (One can almost convert a piano into a harpsichord by using a teaspoon for a hammer.) When a player hits a key on the piano, the action gives the hammer a throw; at the moment when the hammer strikes a string it is not connected with the key, but is flying freely. It is as if the player were throwing soft balls at the strings from a distance. Once the hammer is on its free way, the player can do nothing more to it. His only control is

VIOLIN MUSIC recorded by visible speech apparatus shows a horizontal band for each harmonic produced by the instrument. Large number of bands illustrates complex nature of musical sounds. Record shows passage from Glazounov's "Concerto in A Minor," played by Jascha Heifetz.





COMPLEX WAVE FORMS of musical sounds are the result of combining several simple forms. The forms above are (1) the simple tone of a tuning fork, (2) pure chord produced by four tuning forks struck together, (3) "beat" tone of two tuning forks with almost the same frequency. Characteristic instrumental forms were made by (4) violin, (5) oboe, (6) French horn.

through the initial speed he imparts to the hammer. Thus it is a fact that for a given hammer speed the tone is exactly the same whether the key is pressed by the finger of a great artist or by the tip of an umbrella. Any skeptic to whom this statement is repulsive should open up a piano and watch the motion of a hammer. Piano "touch" is of course a mixture of effects: besides hammer speed, which affects loudness and tone color, it depends on the sequence of tones, the length of time each key is held, the management of the pedals, the phrasing and so on. Of these the last three are perhaps the most important.

There are two subjects in musical acoustics, incidentally, which often arouse furious arguments. One is piano touch. The other is the alleged characteristic flavor of music in different keys. Pupils are often taught that D major is a martial key. Today military marches are played on a piano whose D is 294 cycles per second. A musician in Mozart's time would have had a D of about 278 cycles per second (our C sharp), since the pitch has risen about a semitone in this interval. If two performances of the same music in different pitches can produce the same impression, then the flavor of the key must come from its name and not from its pitch.

V. Wind Instruments

The wind instruments operate on a very different plan from the strings, and as sound-producers they are much more efficient. A stringed instrument loses considerable energy in transmitting its vibrations from the plate to the air; in a wind instrument the sound is emitted directly by vibrations of the air inside the pipe. Hence an instrument like the oboe or clarinet in the orchestra stands out against the string section, and two or three of them are considered sufficient to balance a much larger group of violins.

The sound waves in wind instruments are generated in a variety of ways: by thin streams of air issuing from slots (the organ) or from the player's lips (flute); by the vibrations of single reeds of cane (clarinet family), of double reeds of cane (oboe family), of metal (organ), or of the player's lips (cornet, horn). Except in the case of a metal reed, which has to be tuned to its pipe, the mechanism that excites a wind instrument has no very definite natural frequency but will accommodate itself to the rate of the vibration of the air in the pipe. This rate is determined by the time it takes an exciting air impulse, traveling with the speed of sound (about 1,100 feet a second), to go down the pipe and back. In instruments which have side holes, this wave is reflected not from the end of the pipe but from the first hole that is open. By this means the player controls the effective length of the pipe and the frequency or pitch of the sound produced. Shortening

the pipe by opening successive holes makes it possible to produce the notes of the musical scale; the higher tones are obtained as harmonics of these fundamental vibrations. The sound of the flute comes from two holes, the one at the mouthpiece and the first open one lower down; the vibrating air dances in and out of these two holes simultaneously. The holes still lower down emit practically no sound. The same principles apply to the oboe or clarinet except that there is no hole in the mouthpiece. The lowest tone is the only one whose sound issues from the end of the instrument.

In the brass instruments, the length of the tube is governed either by a sliding piece (slide trombone) or by insertion of additional lengths of pipe by means of valves operated with the fingers. At each length a large series of harmonics can be blown, and with several lengths available all the notes of the scale can be played, many of them in more than one way. The fundamental tones are not often used.

The tone colors of wind instruments are not as variable as those of violins; hence the player's opportunities for virtuosity are more limited. On the organ, the only wind instrument that has separate pipes for each pitch, the organist can build up tone colors by combining pipes of the same pitch but different colors. In the brass instruments, a player produces a marked change in tone color when he puts his fist or some other object in the "bell" from which the sound comes. This muting of the tone corresponds to what happens when one loads the bridge of a violin with an extra weight

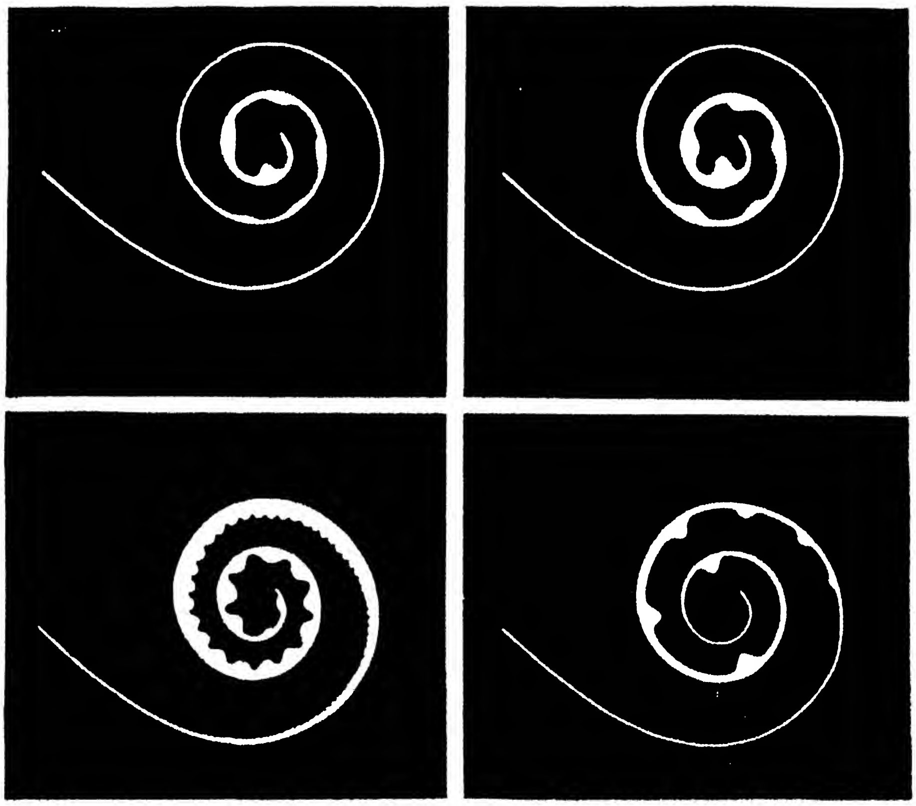
VI. The Singing Voice

But none of these instruments has the variety of tone color available to a singer. The voice is the most versatile and expressive of all musical instruments.

The vocal cords vibrate somewhat as do the lips of a cornet player, that is, as a double reed. They produce a range of fundamental frequencies which is determined by the muscular tension that can be put on them and by their effective mass and length. The action of the cords has recently been photographed with a motion-picture camera, showing that they have a complicated, sinuous back-and-forth motion. Such a motion would be expected to generate a complex sound wave; voice sounds are indeed found to be rich in harmonics.

The throat and mouth space through which the sound passes on its way out can take the form of one chamber or be divided almost in two by the back of the tongue. A singer also varies the size of the mouth opening. These alterations enable the chamber to resonate to a variety of frequencies, some low as fundamentals, some high as harmonics. In singing, we presumably tune the chamber to resonate with the vocal cords at their fundamental

INNER EAR, here shown in highly diagrammatic drawing, is detector of sound. Spiral organ at right is the cochlea. From it run branches of the auditory nerve (*upper right*). These branches are attached to the basilar membrane, stretched across the cochlea's inside diameter along its full length. When sound vibrates membrane, nerve impulses are sent to the brain.



BASILAR MEMBRANE responds to various frequencies at various points along its length. Peaks on spiral diagrams show relative response. Two drawings at top show "false harmonics" of ear's response to a pure tone of increasing loudness. Two drawings below show membrane's accurate response to many harmonics of steamboat whistle (*left*) and note of a bugle (*right*).

or some harmonic. In general the pitch of the voice varies with the tension and length of the cords, its quality depends on the shape and size of the chamber, its loudness is determined by the amount of air pressure supplied by the lungs. The versatility of the voice comes from the ease and quickness with which all these changes can be made.

Singing teachers use certain special terms to describe all the processes involved in tone production. Although these terms have quite definite meanings to the teachers, to others such descriptions as "head tones," "chest register," and "tone placement" mean very little, and that little is probably misleading. One would suppose, for example, that the head and chest must vibrate somewhat at all times, and that the tone must always originate in the same place. One may also object to crediting the bony cavities in the head and the absorbent lung-space with helping to produce loud sounds, since these areas are powerless to contribute anything appreciable. It is to be hoped that before long there will be further experimental studies that will disclose the real behavior of the whole vocal apparatus, and that then such language can be used as will be understood by all.

VII. Musical Scales

There is one special study in which mathematics and music go hand in hand. This is in the construction of musical scales. People with unmusical ears sing up and down the range of pitches without hitting the same spot twice; but music cannot be built on this plan. The piano must have a pattern on its keyboard, and a fixed frequency for each key, as the flute has fixed positions for its side holes. The pattern of the keyboard repeats itself in each octave. An octave is measured by the first interval in the harmonic series. Two tones an octave apart have a frequency ratio of 2 to 1; they produce in our ears a simple motion and a pleasant impression. To produce a similarly pleasing effect within the octave, its intervals also should be simple, with ratios like the ones found in the harmonic series, such as the musical fifth (ratio 3 to 2) and the fourth (4 to 3). Thus the scale is built up on the plan of having as many pairs of tones as possible which please us when sounded together. At the same time the musician demands freedom to shift keys without running into any trouble with different sorts of intervals.

The final result is a scale of 12 notes with semitone intervals all exactly alike, and just filling an octave. The mathematician tells us that if we multiply the frequency of any starting note by the 12th root of two (or 1.05946), we obtain the frequency of the next higher note, and if we continue this process, after 12 multiplications we arrive at the beginning of the next octave. This scale does not give us perfect musical intervals inside the octave, but there seems to be no way in which we can get a better one to fit all the conditions stated. The purist objects; he has a wonderful ear and he says it hurts to hear these intervals the least bit off. So the mathematician writes another paper on a perfect—but unusable—scale.

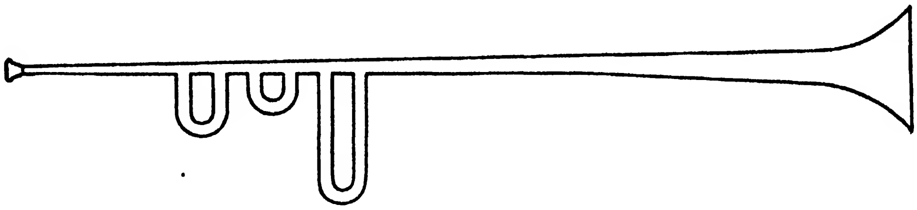
Recently the physicist and the psychologist have joined in the discussion. A new measuring device has been invented by O. L. Railsback, which he calls the chromatic stroboscope. With this he can measure the frequency of any tone while it is sounding, with a precision greater than we may ever need. It has been used to check the tuning of pianos. The results show that expert tuners agree among themselves but they tune the low notes too low and the high ones too high to fit the scale. They do this because it actually sounds better, and the explanation of this odd fact is that the harmonics of a piano string are themselves out of tune, and are sharper than they should be. The 14th harmonic occurs about where the 15th belongs. The scale that results is no longer the exact scale of "equal temperament," which we have just considered, but a "spread" one whose octave ratio is slightly greater than two to one, while its fifths are almost true. All these years we have been using two scales without knowing it. To make matters worse, it has been shown that, in contrast to the piano, the harmonics of pipes and of bowed strings are not out of tune; so that the organ is presumably tuned in equal temperament. The violin is always tuned to perfect fifths, yet nobody minds when it is played with a piano tuned to a different scale. These strange differences seem to have escaped the notice even of our friend the purist.

Recently musical psychologists of the University of Iowa, under the leadership of Dr. C. E. Seashore, have measured the performance of a number of first-class professional singers and violinists, and found that they do not use the scale of equal temperament nor any other scale exactly. We must all be less sensitive to the refinements of tuning than was supposed. The scale (or scales) we now use is quite good enough for such ears as the best of us possess.

VIII. The Listening Ear

The ear, in fact, is a surprising organ; it does not always tell the strict truth. S. S. Stevens of Harvard University has shown that the pitch of a pure tone varies with its loudness. Low tones may drop a whole tone on the musical scale, while very high tones go the other way. If, while listening to a loud tone whose pitch is off, you cover your ears, the pitch goes back to where it belongs. Fortunately, since this effect is observed to an appreciable degree only for pure tones, it is of little importance in listening to most music, because the tones are complex. Moreover, at the pitch where the ear is most sensitive (2,000 cycles per second), the effect disappears.

The ear may even manufacture sounds that do not exist. Harvey Fletcher and his group at the Bell Telephone Laboratories have found that as the loudness of a pure tone increases, the ear begins to hear a change of tone color, seemingly caused by harmonics which appear in the tone in increasing number and strength. The tone increases in shrillness and harshness until it sounds like the blast of a cornet in one's ear. Yet an oscilloscope picture of the wave form of the sound shows no trace of these harmonics.



BRASS INSTRUMENT is stretched out to illustrate function of valves. Manipulating valves adds extra segments to effective length of pipe. This changes the rate of vibration of air in pipe and frequencies of its tones.

These ghostly harmonics arise somehow in the ear itself. The sensitive basilar membrane, where sound is detected by a series of nerve endings, has been proved to respond to different frequencies at different positions along its length. The membrane is spiral-shaped, and Fletcher pictures its "auditory patterns" by means of a set of spiral diagrams showing where disturbances occur in response to sounds of different pitch. In the case of a soft, pure tone, the membrane is disturbed only at the place appropriate to the frequency. But as the same tone grows louder, new disturbances mysteriously appear at the points where the harmonics of this tone would be recorded. The source of the false harmonics is probably traceable to a natural imperfection in the action of the mechanism of the middle ear.

A practical consequence of this quirk is that any tone, pure or complex, increases greatly in harshness as it becomes louder. Thus even a good radio gives a bad tone when turned up too loud; the ear is to be blamed, not the radio set. A violin has a harsher tone to the ear of the player than to a listener some distance away. A violin whose sound was amplified electrically to fill a large hall would sound quite unnatural.

IX. Room Acoustics

Science has made a very considerable contribution to music in connection with the acoustics of halls. To make clear the nature of this contribution we must consider some of the facts about sound in rooms. If the source of sound in a room is suddenly stopped, the sound lasts a little while; it dies down as it is absorbed or escapes through openings. The duration of this sound is long if the room is large or if the sound was a loud one; it is shortened if many absorbing substances are present. The absorptivity of a material is great if it is full of fine pores in which the regular vibrations that constitute sound are made irregular and thus turned into heat.

The best absorptive material is a closely packed audience. But porous plates of various sorts are available for covering walls or ceilings to cut down reflection of sound and increase absorption, in case the audience is not large enough. A bare room with hard walls reflects excellently, and this has two effects: the sound is made louder (just as white walls make a room lighter), and it is prolonged. Speech becomes hard to understand, because successive syllables overlap. Music usually benefits more by reflection than speech does: it has fewer short "syllables," and the reflections can make it loud enough to be heard well even in the rear seats of a very large hall.

Wallace Sabine of Harvard was the first to work out the proper way of correcting the acoustics of noisy halls by increasing their absorptivity. He founded architectural acoustics, which is fast becoming an exact science. It is now a simple matter to provide for good acoustics in a hall before it is built, and a bad hall can usually be made tolerable by treatment at any time.

One musical application of acoustics concerns the marked effect which the character of a room may have on the tone color and the loudness of a voice or other musical instrument. Most absorptive materials absorb more of the high tones than the low ones. When you select a piano in a bare showroom, it is likely to have a "brilliant" tone, meaning that it is strong in high frequencies. But if you place the same piano in a living room full of stuffed furniture, cushions and thick carpets, you may find its tone dull and weak. The high frequencies are still present, but they are quickly absorbed, and so you do not get the reinforcement of these tones that occurred in the showroom. A violin's tone color and power likewise depend on the sort of room in which it is played. On the other hand, a singer whose shrill high tones are hard to bear in an ordinary room should bring along a truckload of cushions, the presence of which would have the effect of greatly increasing the listeners' pleasure.

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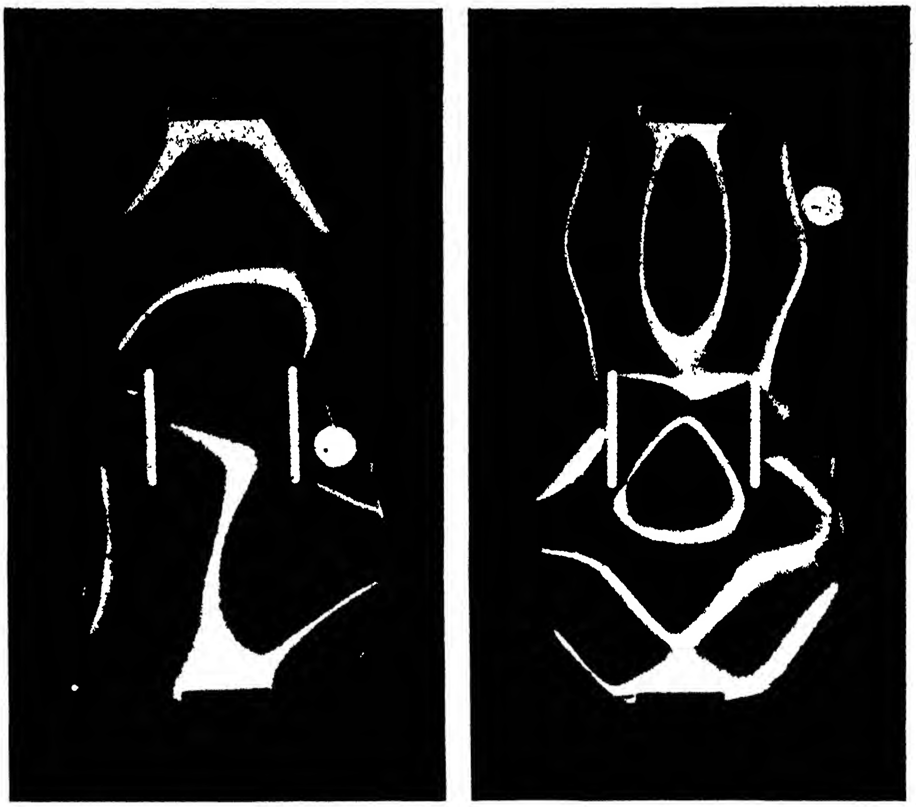
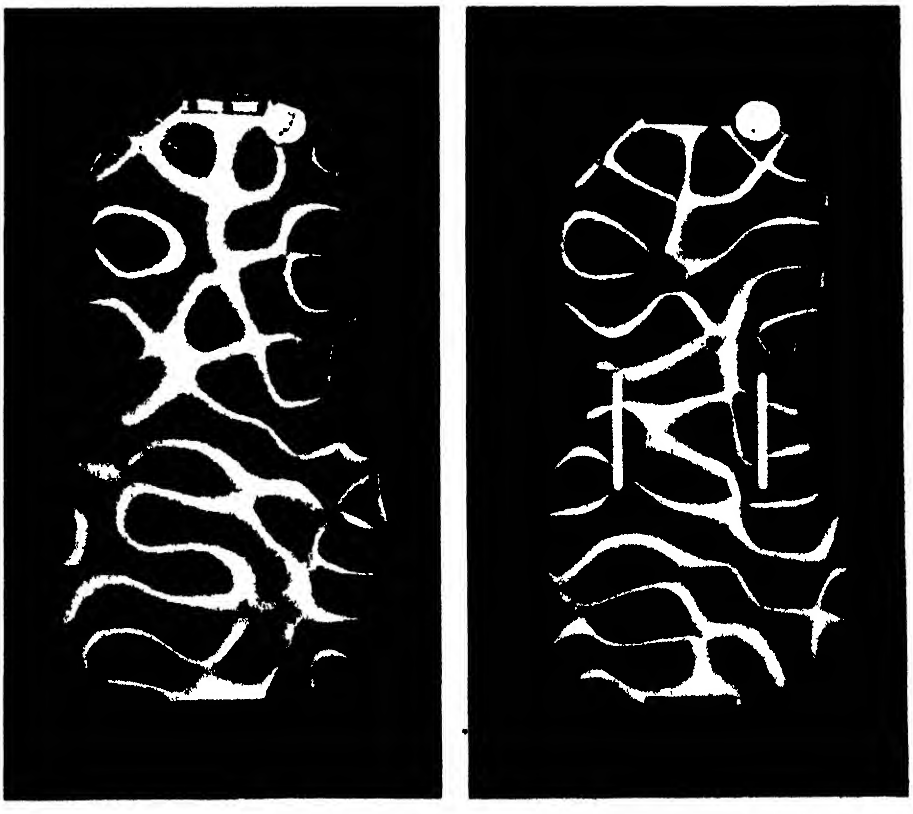


CHLADNI PLATES indicate the vibration of the body of a violin. These patterns were produced by covering a violin-shaped brass plate with sand and drawing a violin bow across its edge. When the bow caused the plate to vibrate, the sand concentrated along quiet nodes between the vibrating areas. Bowing the plate at various points, indicated by round white marker, produces different frequencies of vibration and different patterns. Low tones produce a pattern of a few large areas: high tones a pattern of many small areas. Violin bodies have a few such natural modes of vibration which tend to strengthen certain tones sounded by the strings. Poor violin bodies accentuate squeaky top notes. This sand-and-plate method of analysis was devised 150 years ago by the German acoustical physicist Ernst Chladni.



COMPOUND EYES (*left and right*) of the housefly are bulging domes of many tiny lenses. Behind each lens extends a separate shaft to fly's light-sensitive organ.

INSECT VISION

The compound eye of this vast living order, the practical solution to a difficult optical problem, reproduces a world of coarse images

by Lorus J. and Margery J. Milne

ALTHOUGH man has managed to achieve a working relationship with most animals, it is doubtful that he will ever get along smoothly with the insects. Even if other differences are ignored, men and insects are poles apart in their vision. Not only strategically but biologically they are incapable of seeing eye to eye. Human eyes and insect eyes are built on plans so radically unlike that man has only a dim notion of how the world looks to a mosquito.

We know pretty well what a whale sees. Or a mouse, an elephant, a bat, a cat. They see approximately as we do. The eagle from its aerie, the snake in the grass, the turtle on the lily pad and the minnow darting below have various vantage points but very similar eyes. We can even guess with some certainty how the sea looks to a squid. All of these animals have visual organs much like our own, with an almost spherical eyeball containing a pigmented iris around a pupil. Light passing through the pupil is focused by a doubly convex lens on a sensitive retina. The image on the retina is as precise as that on light-sensitive film in a camera, and it is formed in much the same way.

An insect's eye is radically different in design. It has to be because of its small size. Eyes of the camera type produce poorer and poorer pictures when they are reduced below certain minimum dimensions, for the pupil then becomes so minute that no recognizable image can be formed by light passing through it. The smallest camera-type eye is that of the tiny shrew; the eye of this inch-long creature is only a twenty-fifth of an inch in diameter. This is actually too small to do the animal much good—the shrew is almost blind. Camera eyes less than an eighth of an inch in diameter are poor visual organs, found only in animals that depend on them very little. This principle is well known to photographers. Seldom can the iris diaphragm on even a good camera lens be closed to leave an opening less than a tenth of an inch in diameter. Sometimes users of small cameras wonder why their lenses will not stop down farther to match bright subject matter. This is the answer: resolution suffers by further pinholing.

Only an insignificant number of the 800,000 insect species are big enough to carry a camera-type eye that would work well. The smallest insects that see are about a hundredth of an inch long. Eyes of insect dimensions need a new principle, and the design they have developed is known as the compound eye. This design is universal in insects: even the largest of them, which are between six and seven inches long and could see with camera eyes, have compound eyes like their fellows.

The compound eye does away altogether with true images. In their stead, the insect's visual organ makes use of a mosaic of information on the relative brightness of various parts of the surrounding scene. The eye itself is composed of a small or large number of identical units, arranged side by side in close formation like seeds in a sycamore ball. Sometimes this arrangement is described as resembling the filled cells of a honeycomb. The comparison is not exact, for the bees make their cells with parallel walls, and the units of the compound eye are long cones. Only by being so can they fit together like the sycamore seeds to give a convex surface to the group. And this convex surface is one of the most important features of the insect eye.

In a sycamore ball each seed has an axis of symmetry—an imaginary lengthwise line that radiates outward from the center of the ball. The units of the compound eye (called ommatidia) also have axes of symmetry that fan out. These axes are the lines of sight for the individual ommatidia, and each aims at a separate part of the environment that surrounds the insect.

Although the compound eye does not rely on images as does the camera type, each ommatidium has its individual lens. These lenses are very transparent and *could* produce an image deep in the eye in the region of the light-sensitive cells. But between the lens and the receiving end of the system is interposed a pigment diaphragm with a minute central aperture. Unless the light passes through this tiny hole it cannot reach the retinal cells that alone can send a message to the brain. Only light rays from a definite region on or near the axis of the ommatidium are led through the aperture by the converging action of the lens. At the same time the pinhole blurs the image to some shade of gray, light or dark, something the sense cells are able to measure as values of brightness. And since each ommatidium of a compound eye faces in a slightly different direction from any other (like the sycamore seeds), its responsibility is restricted to one particular portion of the surrounding space. The barely overlapping fuzzy images of the ommatidia, all added together, represent to the insect the world it lives in.

THIS detailless type of image is not necessarily bad or good. It is more familiar to us than many realize. Halftone illustrations in books and newspapers are somewhat similar, since the illusion of a photograph is built up from jet-black ink on white paper through the varying sizes of a close and regular pattern of fine dots. The printer has no gray inks with which to render shades of tone. He employs a trick "screen" to produce dots of different sizes, but all of equal blackness. He assumes rightly that readers will not look for extra detail in the halftone by examining his product with a lens. Actually the detail is not there. Magnification reveals only the pattern. The excellence of the reproduction (and illusion) depends on the number of dots per inch—on the fineness of the screen. Similarly the mosaic picture characteristic of insect vision depends for detail on the size of the ommatidia. The smaller and more closely packed they are, the more restricted is the field of view of each unit, and the finer the detail the creature can recognize in its environment. Insects like the dragonfly have immense numbers of minute ommatidia packed into a great bulging compound eye that covers most of the head, allowing them the acuity of vision needed for darting after gnats and mosquitoes. By comparison a grasshopper's vision is very crude, its ommatidia coarse and relatively few

Even a small dragonfly has far better vision than one of the lesser mammals such as a mouse. Furthermore, the insect eye plan allows almost equally good seeing forward, up, down, to the sides and far astern—all at the same time and without shifting the head. To accomplish this it is necessary only to have the compound eye include more ommatidia, so that the extras can cover additional parts of the surrounding scene. Few have bettered the dragonfly in this, for its right eye extends to the top of its head to meet the left eye on the mid-line. In fact, almost the whole head is occupied with visual units Space is left only for the neck and a small region in front and below where the antennae and mouth parts are located.

Because of the bulbous form of the dragonfly's eyes, there are ommatidia in both the right and left eyes that stare straight ahead of the insect. Others slightly toward the mid-line converge to overlap fields at various distances in advance of the creature. The same is true slightly to the side, above and below. Thus the dragonfly has true binocular vision, and with it comes the highly useful ability to gauge distance and depth. On this the insect depends in chasing down its active, dodging victims. Whether the prospective prey zooms or dives, the dragonfly does not lose sight of it. The pattern representing the victim merely shifts to other ommatidia in the binocular field. Only to the rear, where its own muscular body obstructs the view, is a dragonfly blind. Small boys know that a butterfly net swept *after* a dragonfly is more likely to capture it than one from front or side, where the insect sees a warning flash of movement.

Binocular vision and depth perception are part of the essential equipment of insects that hunt living animals by sight. They are features of the praying mantis, horsefly, tsetse fly, water strider, back swimmer, tiger beetle and hunting wasp. Vegetarian insects do not require this sort of vision. Their food does not run away. Thus lateral placement of the less well-developed eyes of the grasshopper allows more space inside the insect's head for its chewing muscles and their attachments. Chewing is most important to a plant eater, since it must munch through prodigious quantities of greenery to gain an appreciable amount of nourishment.

An insect evinces the greatest response to movement and to actions close by. The shifting of any object causes a pattern of light or dark to move over the mosaic of ommatidia. The closer the object, the more ommatidia will be affected. And the more ommatidia that telegraph news of contrasts in brightness to the insect's brain, the more the animal responds. For this reason a large dark disk moving in front of a white background is not nearly as effective in disturbing the possessor of a compound eye as an equal area broken up into coarse spots like a checkerboard. Yet this increase in "contrast contour" has its

IN DAYTIME praying mantis has bright green eyes. Dark spot toward the top of each eye is "false pupil," marking lenses that point directly toward the observer.

AT NIGHT green pigment in mantis' eye migrates, leaving eye chocolate brown. Eye then gathers more light. Mantis is one of a few species with this adaptive power.

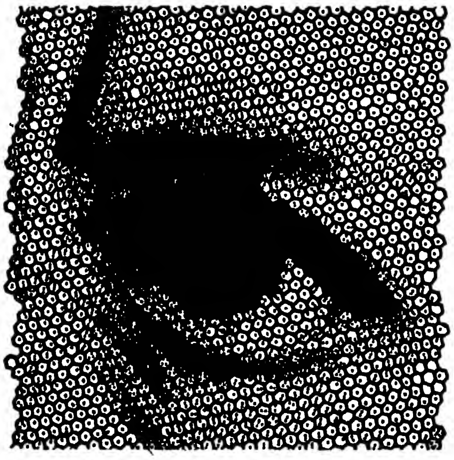
limits, for a very fine pattern is not seen at all. The most stimulating is one that has spots matching in dimensions the field of view of a single ommatidium at a given distance. Hence a coarse pattern is effective from a greater distance, a finer one nearby. It is a matter of angle—and this feature varies from one kind of insect to another. In the housefly, for example, the most stimulating pattern has spots three degrees across. These are the smallest that the ommatidia will recognize as distinct. The three degrees is a measure of the fly's visual acuity. The honeybee distinguishes patterns one degree in size. This is still only one-sixtieth as good a performance as that of a human eye with normal "20/20 vision."

OUR own vision, so much richer in detail, may be seriously upset by refractive errors. Thus a nearsighted person cannot focus an image of distant objects unless aided by spectacle lenses of the divergent type. Near objects, on the other hand, are not only distinct but actually magnified considerably, so that a myopic individual sees more detail at close range than does a normal person. A compound eye, because of its low visual acuity, behaves somewhat like a nearsighted human eye. An object close to an insect affects many ommatidia and vision is relatively distinct. But as the object moves farther away, fewer and fewer of the eye units are directed toward it. Details disappear rapidly and soon so few ommatidia are concerned that the object has negligible effect. The deterioration in the mosaic image is at least 60 times as rapid as that in a normal human eye. This means that we can recognize an insect 60 times as far away as it can see its relative with comparable distinctness. Sixty feet versus one foot is the same order of difference as that between a seriously nearsighted person and someone with normal vision. Neither myope nor insect can see the moon distinctly. For the compound eye, the half degree subtended by the full moon (or the sun) may not fill even a single ommatidium with light. The brilliance produced by sun or moon on flowers and landscape may stimulate the insect, but the celestial bodies themselves cannot.

The relationship between size of object and its interest for an insect can be demonstrated with a butterfly in a dark room with black walls. If a bare electric bulb is turned on, the butterfly will flit toward it. Even if the insect's wings are clipped together to prevent flight, the butterfly will creep in the direction of the bulb. But if a sheet of white paper is held close to the insect on the side opposite the bulb, the butterfly will turn around and walk toward the paper. The bulb is far brighter, but the paper it illuminates has a larger area that stimulates more ommatidia. This is the insect's guide.

To many insects, a flower or group of blossoms is an attractive pattern. Actually, there were no flowers as we know them on this earth until insects appeared. Then plants developed means for making use of bees and other bugs to carry pollen and ensure setting of fruit—a method less wasteful than casting immense quantities of pollen into the wind to be blown to a waiting unfertilized ovary. Yet to attract an insect requires first something to see (the petals), then something to present a reward (the nectar or pollen). Anyone doubting the importance of the visual stimulus can prove the point by pulling

HALFTONE engraving, here enlarged, creates effect of shading with one ink and dots of various sizes.



MOSAIC IMAGE of insect eye operates on similar principle. Each lens system detects single tone of scene.

the petals from a branch of apple flowers. The nectaries are still there. So is the pollen. But the bees will do no more than hover over the petalless blossoms. Never do they alight and collect the reward they so eagerly seek.

The apple tree presents another demonstration of what an insect sees. On a perfectly still day, honeybees come to the apple blossoms indiscriminately. But if there are two trees with unequal exposure to a breeze, the tree that sways gently and flutters its flowers is far more populous with bees than the tree that stands calmly in the sheltering lee of some building. If the wind shifts so that both trees are disturbed equally, the insects redistribute their attention. To a bee cruising overhead, the quiet tree appears as a pinkish-white area that moves slowly across its visual mosaic in accordance with the insect's flight. Fluttering flowers, on the other hand, stimulate and restimulate ommatidia in a manner that is independent of the insect's own motion. They draw attention to themselves and flag the insect down. So does a wildly swatting man trying to drive away an angry hornet. Stay still and you will almost disappear!

EVEN the rapid waving of petals in a high wind does not present a movement too fast for the insect's eye to follow. Experimenters have held bees in front of screens on which were projected alternating stripes of dark and light. If the pattern was shifted to the left, the bee followed the motion with its antennae—extending the left antenna straight to the side, the right antenna dead ahead. So long as the pattern stripes were one degree across (for maximum use of the bee's visual acuity) and the contrast in brightness was high, the insect continued to recognize the direction of movement when the stripes flickered at the rate of 50 to 60 per minute. This is as good performance as can be expected of a human eye. Those who have experienced the uneven illumination of lamps run on electric power generated at Niagara Falls know that their fluttering, at the rate of 50 flickers per minute, is only barely perceptible.

The flickering of an ordinary electric bulb would not be apparent to a honeybee, however. The difference between the dim and bright phases offers insufficient contrast. Similarly in the shifting pattern experiment, the full measure of flicker recognition is obtained only with very light and very dark stripings. If the contrast is reduced, so is the highest recognizable rate of flicker. By studying insect behavior in this way it has been possible to show that the compound visual mechanism requires a contrast at least 20 times as great as is necessary to gain recognition in the camera-type eye. This tells us that for the insect the tonal range from black to white contains about a twentieth as many shades of gray as the human eye can identify distinctly.

Related to this deficiency of grays in the vision of insects is their response to darkness. The range of brightness between a sun-drenched beach and a shadowed woodland under a starlit, moonless sky is about a billion to one. Human eyes can adapt themselves throughout this tremendous spread. But an insect that is active only in daytime believes that night is at hand if the illumination drops suddenly to a hundredth of the sunshine level. The insect may go to sleep promptly, as many brave souls know who have captured a bumblebee in hands cupped together around the buzzing

insect when it backed from a flower. Try it! Don't be alarmed when the captive shrills a warning as it creeps around the closed surface of your palms. The sudden darkness overcomes its concern, and it quiets down with astonishing speed. Several seconds of direct sunlight are required to awaken the sleeping bee again. During the twilight of solar eclipses almost the whole insect population goes to sleep. The ability of the compound eye to adapt to the dark is relatively poor. Even when allowed an hour to grow accustomed to the dark, the compound eye needs a thousandth of full illumination to see, whereas the human eye needs only a billionth. For this reason, if no other, daytime insects do not awaken with the birds, but stay quiet on their sleeping sites until the sun has cleared the horizon and filled the shadowed spots with light.

Many insects, of course, are abroad at night. But they depend more on odors than on vision in finding their way about. Most night-flowering plants that rely for pollination upon sphinx moths, owlets and other insects are highly odoriferous (like the honeysuckle, evening primrose and nightshade) or have very large white blossoms (like the Jimson weed). Many of the nocturnal insects have become adapted to the darkness in another way: their eyes lack the pigment diaphragm that limits the light for day-flying kinds. Thus they have sacrificed the only mechanism available to the compound eye for achieving high acuity of vision, but they have gained an advantage. Without the pigment interference, light entering a number of adjacent ommatidia lenses can be refracted and fall on the same sense cells. The image that results is fuzzier, but it gains in brightness. Some insects that are active in twilight hours actually shift their eye pigments to suit the circumstances. The praying mantis' eyes, except for the black false pupils, are pale green by day, matching its body. By night the same eyes are chocolate brown—so dark that the false pupils scarcely show. Pigment from deep in the eye has been shifted to the surface to allow the ommatidia to act "one for all and all for one"—not each to itself as in the daytime condition.

The compound eye recognizes colors in its surroundings. Indeed, the insect can see where we cannot, in the ultraviolet part of the sun's spectrum. To the honeybee, at least, this ultraviolet region is a distinct "color" that the insect can distinguish from the portions of the spectrum visible to us—violet, blue, green, yellow, orange and red. The little fruit fly, *Drosophila*, the familiar experimental organism of modern heredity studies, is attracted very strongly to light of any wavelength from the short ultraviolet into the longer yellowish-orange. But as though by compensation, the honeybee, the fruit fly and most other insects are completely blind to red light. This, by the way, is another reason why dawn and sunset hours provide too little illumination for insects to be active. The longer passage of the sun's rays obliquely through the atmosphere filters out much of the blue end of the spectrum with which the insect sees. Some of the fireflies prove, however, that insect eyes have possibilities far into the long waves too. Pure spectral red light, flashed at the proper interval after a male on the prowl has emitted his signaling glow, is sufficiently close imitation of the green from a responding female to lure the swains in numbers to the experimenter.

Bees of various kinds show a remarkable "color constancy" in visiting flowers. Attempts have often been made to confuse them with squares of cardboard laid out in a random arrangement. Where most of the cardboards are gray of varying darknesses and the other cards are colors including some that match the flowers nearby, the bees fly to and hover over the matching cards. They pay no attention whatever to the grays or wrong colors. This evidence of color vision indicates that honeybees and bumblebees, at least, can distinguish yellow and green (together as one "color") from blue-green, from blue and violet, and from ultraviolet. These four regions of the spectrum are true colors to the insects, and they never confuse them with any shade of gray. But variations within these regions yield no response. Compare this behavior with the 17,250 gradations of hue that the well-trained human eye can distinguish!

The world through an insect's eyes, then, is a drab place in many ways. Yet these insects are part and parcel of the greatest group of competitors man has on this earth. If the insects' vision is inferior to man's, it is nonetheless adequate to their purpose. And if we are to control these dangerous rivals, we must investigate their totally different point of view.

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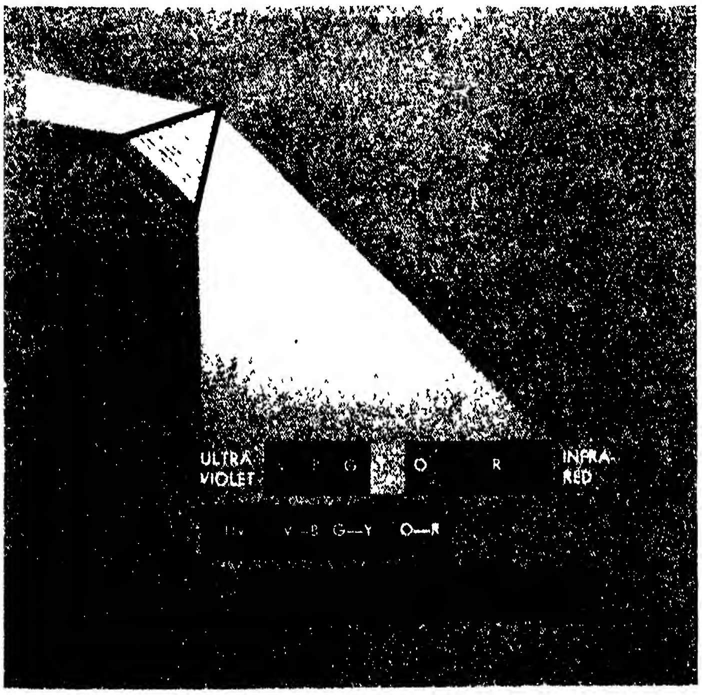
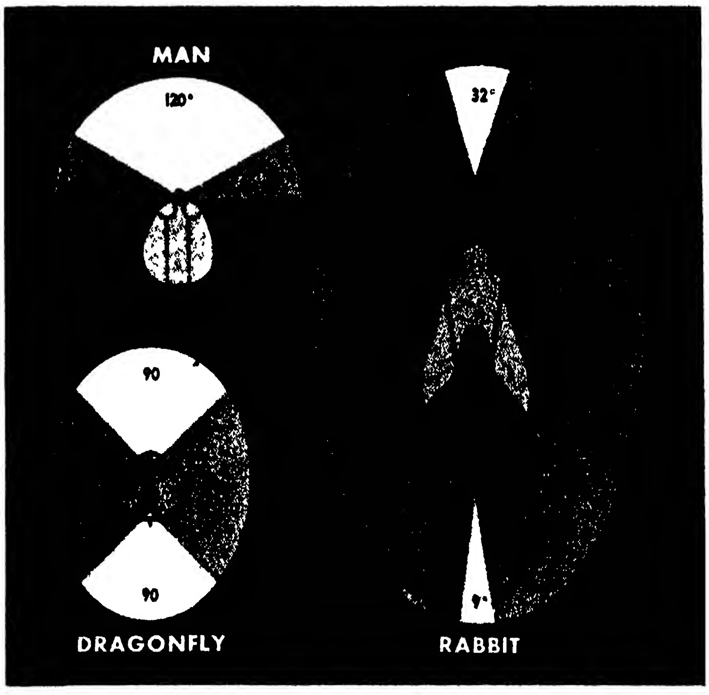
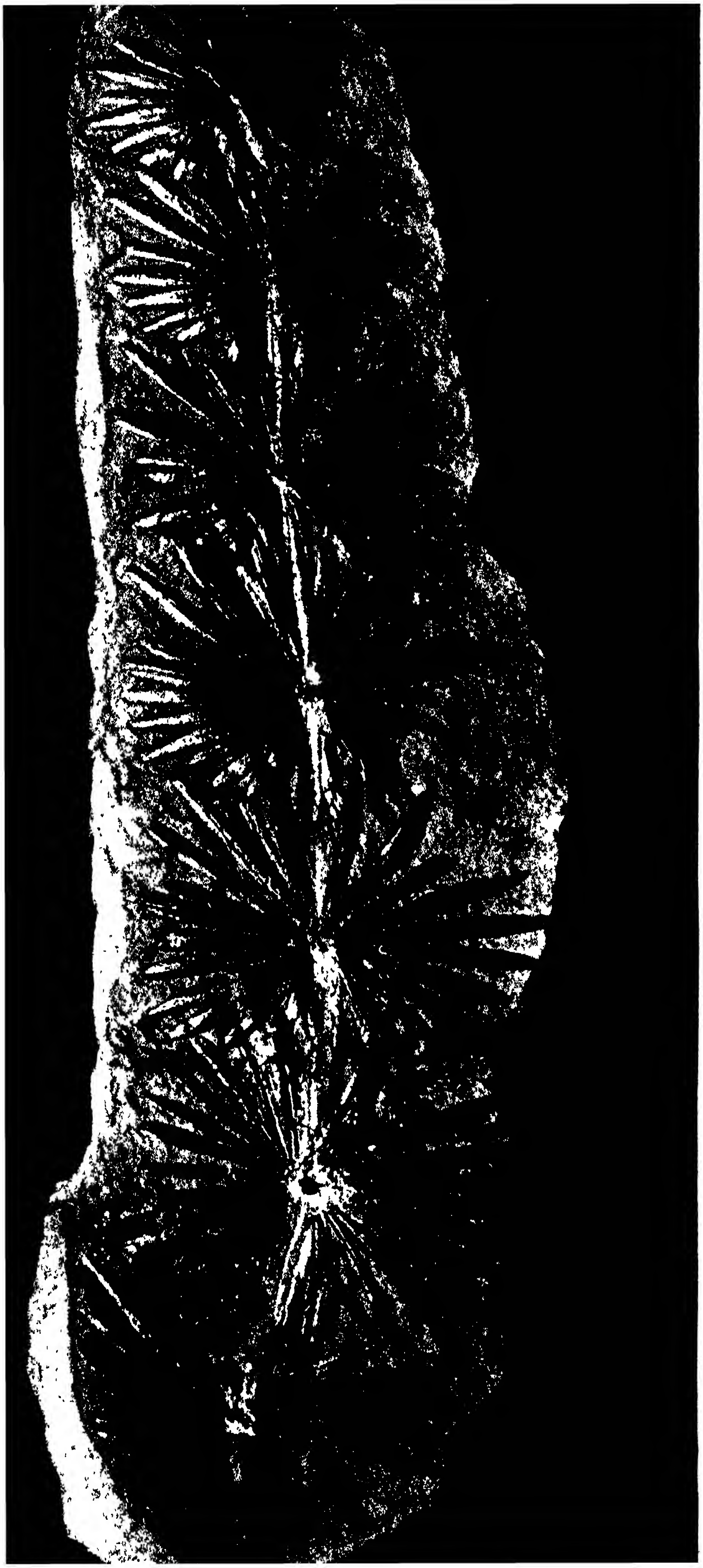


WAVELENGTHS detected by human eye run from violet to red. Fruit fly detects few colors in a shorter wave band. Firefly may have broadest spectrum of vision.



BINOCULAR field in man (*white area*) is broad, but dragonfly also has it astern, with monocular vision to both sides (*light gray*). Rabbit has big monocular field.



THE

COAL ranks with soil and water and air as a vital necessity of 20th-century man. Without it, he could scarcely plan his tomorrow, much less a more abundant future. It is the principal raw material of his technology; indeed, it is not too much to say that coal is man's chief ally in his scientific conquest of the physical world. Coal makes possible the smelting of iron and the making of steel; it builds man's tools, drives his machines, transports his goods, fertilizes his crops, preserves his foods, lights his cities, warms his houses, fights his wars and even cures many of his ills. There is almost no material product of our civilization, from bombs to medicines, that does not owe its existence directly or indirectly to coal. Let its mining be halted for only a few days, and almost immediately trains stop running, factories shut down, lights grow dim, food ceases to flow to market places and a fatal paralysis falls upon man and his civilization.

As the most important deposit which nature has stored in the earth, and as a fascinating natural phenomenon in its own right, this powerful black stuff has been studied for centuries by many specialists--geologists, chemists, botanists, paleobotanists. Yet of such infinite variety and complexity is coal that only recently has the modern method of science determined how it was made.

Strictly speaking, coal is a sedimentary rock, so classified by geologists because it has no fixed chemical formula. Like other rocks, it varies in chemical composition. No bed of coal is precisely like another, and even within the same bed the various parts may differ greatly in chemical structure. Coal is the most complex of all rocks; this is what makes possible its thousands of different uses.

This same complexity also is the cause of the historic argument about coal's origin. Many of the early investigators were led to strange conclusions. In 1546 the German mineralogist Agricola announced that coal was condensed petro-

GIANT RUSH *Calamites* left impression of its leaves in mud which was later metamorphosed into shale.

BEGINNINGS OF COAL

The remains of strange and beautiful plants have preserved solar energy of the geologic past for the uses of man

by Raymond E. Janssen

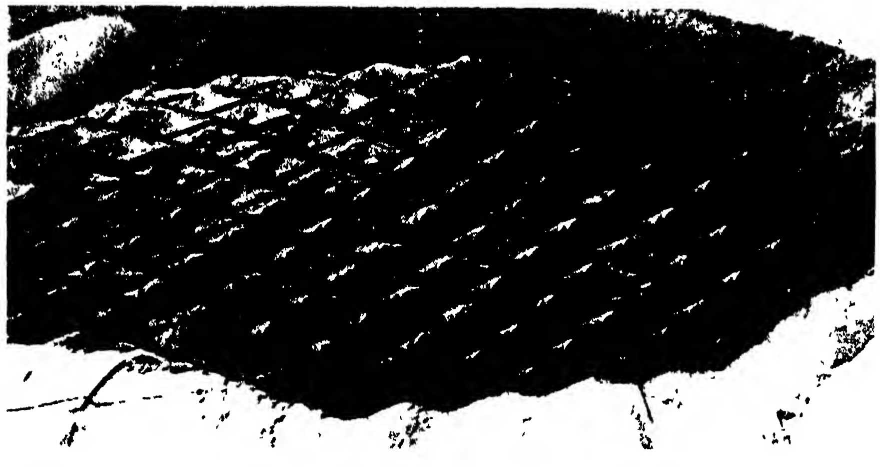
leum. The 18-century Irish mineralogist Richard Kirwan argued that coal originated from the decomposition of the oldest (Archeozoic) earth rocks. A half century later the German chemist Fuchs suggested that coal was formed simply by the precipitation of surplus carbon dioxide in the rocks. As late as 1903 reputable geologists denied that coal could possibly have had an organic origin.

The first to suggest the correct answer was another German named Klein, who in 1592 suspected that bituminous coal and lignite came from wood. In 1709 the German Johann Scheuchzer recognized scattered plant remains in coal—strong support for the theory of its vegetable origin. Still stronger evidence was discovered in 1833 by the English geologist William Hutton: by the use of the microscope he showed that coal contained an abundance of recognizable plant material including cellular structures like those of charcoal. He also observed that shales and sandstones immediately above and below coal beds often showed the fossil imprints of leaves, stems and seeds, spread out as though they were in a herbarium.

Today the plant origin of coal is established beyond debate, and we can reconstruct in exact detail not only the geological processes by which primeval forests were converted into coal but a rather complete picture of the plant life that covered the earth hundreds of millions of years ago. As we shall see, the conditions that created the coal deposits no longer exist to any appreciable extent. So far as man is concerned, nature has made its last important deposit in our bank of coal.

As every schoolboy now knows, coal was formed by the compression of buried masses of plants over periods of millions of years. One basic question that has concerned geologists is whether it was made from land plants or sea plants. The evidence at first strongly suggested that they were sea plants. Most coal beds are overlaid by strata of marine material. Moreover, great accumulations of marine algae, which might be the potential stuff of coal beds, are found along seashores and in huge masses in the open ocean. It was logical, therefore, to assume that coal beds had been deposited on the bottoms of seas. But during the past 50 years microscopic studies of fossilized plant tissues have proved that coal is composed of land plants. Fresh-water plants have rarely been found in it, and marine plants never.

Some have argued that the plants were transported from their original habitats by currents and redeposited in beds beneath the sea. But there are several evidences which indicate beyond doubt that all major beds were formed *in situ*, that is, in the places where the plants grew. The fact that thick beds of pure coal occur unmixed with sand, silt or other sediments is proof in itself that the plant material was not deposited in the sea. Had this been the case, the plant debris would have been interstratified with other sediments. This is the situation which prevails in the strata immediately above the coal beds proper, where isolated plant fossils are found embedded in the shales and sandstones. In order to account for thick beds of pure coal, we must look to present-day boglands where pure plant debris is accumulating in ever-increasing depths beneath the semi-stagnant swamp waters. Here it packs down into peat—the first step in coal-bed formation. Also, in many coal mines the fossil stumps of trees can be seen still standing where once they grew, with roots extending down into the coal bed, or even below the coal and into the shale beneath. These undershales were once the soils in which those trees were rooted. Such evidence can be taken as undeniable proof that the plants which formed the coal were not transported before they were deposited, but that they actually grew in the sites now occupied by the coal beds.



BARK of *Lepidodendron*, a common tree of the Pennsylvanian period, was covered with diamond-shaped scars. Large impressions of fossil plants do not appear in coal itself. They are left in rocks above and below coal beds.

Geological evidence shows that coal has formed in varying quantities ever since land plants began to flourish on the earth. The earliest recognizable fossils of land plants have been found in rocks of the Silurian age, deposited some 400 million years ago. But plants were not then plentiful enough to give rise to extensive coal beds; only one Silurian coal formation—a small deposit in Bohemia—has been found on our entire planet. In the Devonian period, which followed the Silurian, scattered forests began to appear; they formed a few thin coal beds. But most of our great beds derive from the two succeeding periods, the Mississippian and Pennsylvanian, approximately 250 million years ago. Then arose the first towering forests, and a wealth of vegetation that has given to these

STUMP of a fossil tree is preserved in a Nova Scotia coal field. Flora of the Pennsylvanian period almost covered the earth, even growing in what is now Antarctica.

FOSSIL NUTS of the seed fern *Neuropteris* are embedded in a slab of sandstone. Nuts, now borne only by trees, grew only on ferns in the Pennsylvanian period.

two periods the name "Carboniferous." The world's major high-grade coal deposits are found mostly in the strata of the Pennsylvanian period. And, singularly, although land plants have continued to flourish in great abundance ever since, the size of coal beds in the strata succeeding the Pennsylvanian has steadily dwindled

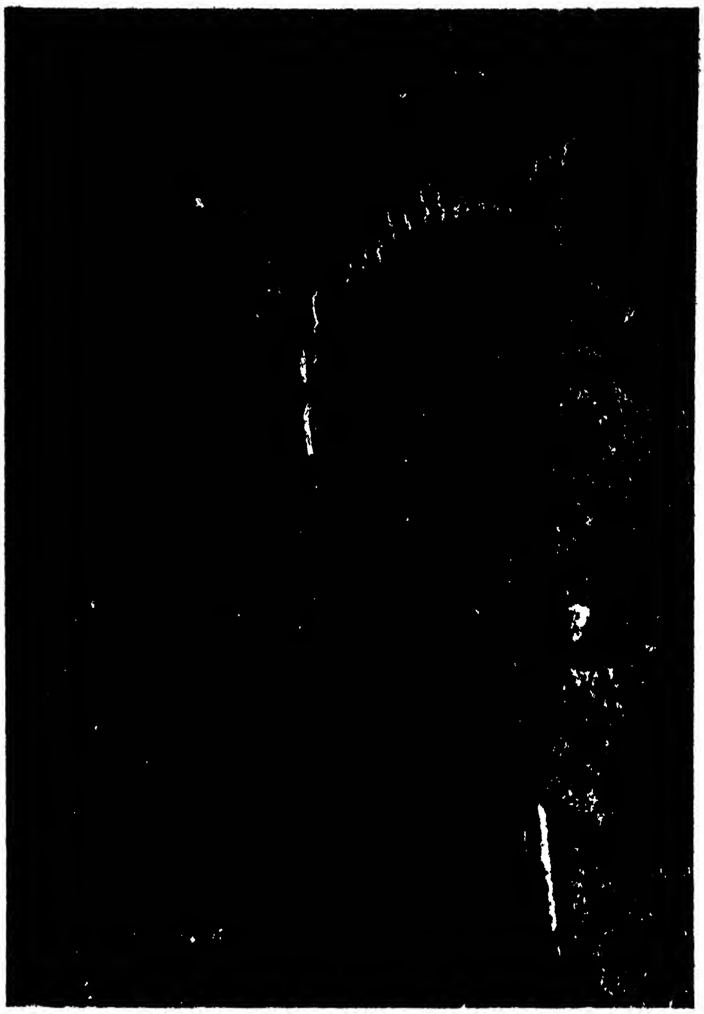
The reason for this is geological. Consider, for example, the geological conditions and processes whereby coal was made in North America in the Pennsylvanian period. The region between the Appalachian and Rocky Mountains was then a vast inland sea. Into it, from the bordering lands, great rivers washed sediments of sand and soil. These sediments, built up by millions of years of erosion, gradually filled many parts of the sea basin and formed deltas that forced the sea to retreat, in much the same way as the delta of the Mississippi River is now encroaching upon the Gulf of Mexico. (Only a few million years ago an arm of the Gulf extended as far north as the Ohio River; it was filled in by the present Mississippi, whose delta actually begins not at New Orleans but at Cairo, Illinois!) The deltas of Pennsylvanian times were vast swamplands, far more extensive than any swamps in the world today. From their mucky soils sprang huge forests, like the bayou jungles that cover the Mississippi Delta today. Their trees grew and died and fell in thick organic masses into the boggy waters.

THEY did not decay, as dead plant material ordinarily does on dry land. In the presence of oxygen, dead plants normally oxidize to carbon dioxide and water, and their decayed remains mix with the soil as humus. But the swamp waters under which the Pennsylvanian trees were buried excluded oxygen and killed even anaerobic bacteria, so the dead organic matter, although partly decomposed, did not entirely rot away. Instead, it became a slimy colloidal mass, the substance now called peat. This peat was of various kinds, some brown and spongy, some black and compact, depending on the amount of decomposition that had taken place.

Over these mucky masses, the sea advanced and laid down new sediments. As the pressure piled up and the buried peat dried and hardened, it was pressed into lignite—low-grade coal. Under the further pressure of eons of deposits, the lignite became bituminous coal. It was under such great pressure by this time that one foot of bituminous coal represented 20 feet of original plant material. Eventually, under even more extreme pressures, part of the bituminous was compacted to anthracite coal. Such pressures develop only where rock strata are folded upward into great mountain ranges, which accounts for the fact that anthracite is found in folded strata alone and is much less abundant than bituminous.

Coal beds are seldom found singly. They almost always lie in great series of layers, separated by layers of other sedimentary rocks. How may one explain this pattern of seam piled on seam, as well as the peculiar fact that the layers between the coal beds are usually of marine origin? Again, geologists have found the answer in the rocks. As the deltas piled up on the sea basin, the basin itself was depressed. Sea bottoms are known to sink from time to time. As the basin sank under the increasing weight of sediments, the swamplands, which were only a few feet above sea level, fell below that level and the sea washed over them. The inundated forests were killed, with some trees

FRONDS of the true fern *Asterotheca miltoni* are imprinted in shale. Ferns ranging up to 70 feet in height were commonest and most diversified plants of period.



BROKEN TRUNK of the giant rush *Calamites suckowi* shows knothole where one of its branches broke off. This specimen was found in a West Virginia coal mine.

falling in the water, and others remaining upright.

NOW marine deposits covered and enclosed them. A new delta arose, and a new cycle began. The delta grew a forest, the forest fell and turned to peat, the compacted mass sank below the sea again and was covered again by new sediments. The cycle repeated itself again and again. In parts of West Virginia more than 100 different seams of coal have been found, one lying above the other, with sea debris in between. From these successive layers, one can read an accurate geographical, geological and botanical history of the Pennsylvanian period, covering 35 million years or more.

It is in the plant life of that ancient time that geologists are naturally most interested. From coal itself little can be learned, for in coal seams the plants have been so altered by extreme pressure that only their cell structures remain for study. But in the sediments immediately above the coal, that is to say, in the roof shale or slate of coal mines, geologists have found many fossils of complete plants, with stems, roots, seeds and leaves which were beautifully preserved, even down to their intricate veins and texture.

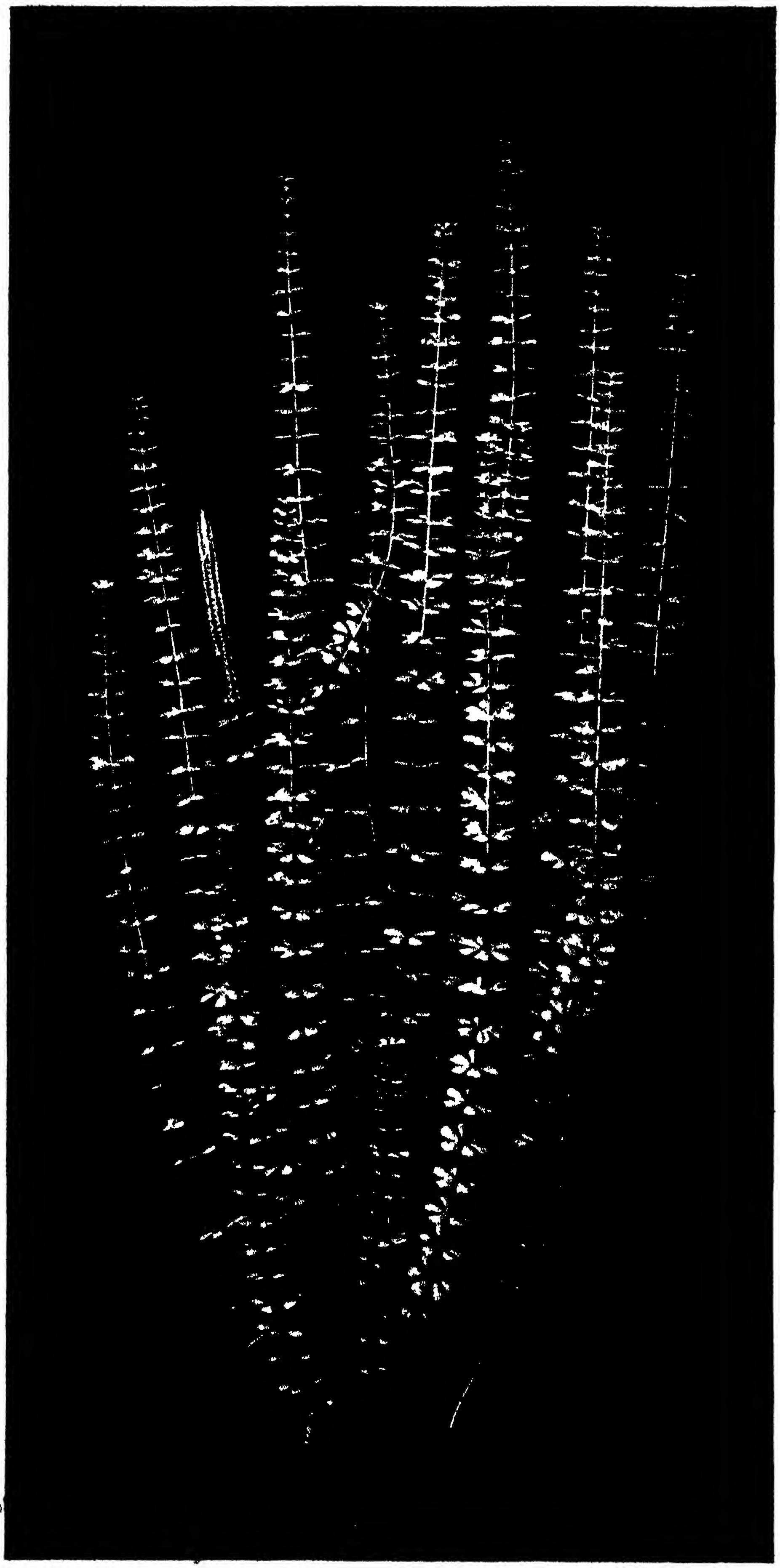
Thanks to the branch of geology known as paleobotany, which has developed greatly since the turn of the century, knowledge of the ancient plants which formed coal has become amazingly complete. Through painstaking and detailed study of countless fossil specimens taken from the world's coal mines, thousands of varieties of coal-age plants, now long extinct, have become known.

The Pennsylvanian plant world was vastly different from ours. There were then no forests of deciduous, broad-leaved trees, no grassy prairies, no flower-carpeted meadows. No pine trees clothed the mountain sides, no palms swayed in the breezes along the shores. These plants were not destined to appear on the earth until millions of years later. The coal swamps were covered instead with an immense, lush growth of plants more like our club mosses, horsetails and ferns. Although these plants were lower forms, botanically speaking, many of them were of gigantic size. The forests were dominated by stately pteridophytes (from the Greek *pteridos*, meaning fern, and *phyton*, plant), which attained the dimensions of large present-day trees. The undergrowth consisted mostly of ferns and other shrubby plants and vines with fernlike foliage.

The principal trees of the coal age were of the botanical order *Lycopodiales*, which then had a much greater variety of forms than it has today. The best-known present members of this order in the temperate zones are *Selaginella*, the club moss, and *Lycopodium*, the ground pine. In the coal age, the dominant Lycopodiales were two huge tree species—*Lepidodendron* and *Sigillaria*. Their most distinctive feature was a peculiar kind of scar on the trunk, representing the former attachment places of fallen leaves. Strangely enough, after the leaves had fallen these leaf scars continued to grow throughout the life of the trees, giving their bark a characteristic pattern quite unlike the rough bark of present-day trees. Hundreds of different scar patterns are known, and it is by such variations that the ancient tree fossils are classified.

The Lepidodendron trees had diamond-shaped, spirally arranged scars on their trunks and branches. The trees branched by twos, each branch dividing repeatedly into two smaller ones to the ultimate tips. At the tips were borne cones containing

the reproductive spores. When ripe, the cones were shed and two new branches began to grow from this point. These in turn bore a new series of cones and the cycle repeated itself. The Sigillaria trees, in sharp contrast, did not branch at all. Instead, they bore their leaves in a single spreading crown at the top of the trunk, much in the fashion of modern palm trees. Their cones were carried on small stems which emerged at irregular intervals along the trunk, like the pod-bearing structures of modern cacao trees. When they fell off they left oval scars resembling knotholes on the trunk.



RECONSTRUCTION of coal-age "weed" *Sphenophyllum* shows its circular leaf pattern and slender reproductive cone (*upper left*). Sphenophyllum seldom grew higher than two feet, carried its leaves in multiples of three.

THE Lepidodendron and Sigillaria leaves were long, grasslike spikes, sometimes as much as three feet in length but never more than half an inch wide. The trees attained heights of 100 feet or more, with trunk diameters of six feet or so at the base. They grew abundantly all over the earth in the coal age, and their stems and leaves were one of the chief constituents in the formation of coal. Cannel coal, which is a special variety of bituminous, is composed almost entirely of the massed spores of these trees.

The great swamplands of the coal age also teemed with gigantic rushes, called *Calamites*, which resembled the modern bamboo. Their enormous trunks were as much as two feet thick at the base and towered 50 feet or more. Jointed like the bamboo, the trunks bore lateral branches, in some species from every joint. Along the full length of every branch, at closely spaced intervals of an inch or two, were whorls of spatula-shaped leaves. Each whorl or cluster had 15 to 30 leaves. Coal miners often mistake these fossils for asters or daisies, for when pressed flat in the rocks the leaf-whorls suggest a flower. These gigantic rushes have left only one small modern descendant: the common roadside weed known variously as horsetail, scouring rush or jointed grass.

The most ubiquitous "weed" of the coal forests was *Sphenophyllum*—a small, slender-branched, herbaceous plant that seldom grew more than two feet high. Its branches sprouted many whorls of tiny triangular or wedge-shaped leaflets, clustered always in multiples of three, the average number in most species being six to twelve. At the branch tips, the weed, like the Calamites rushes, bore reproductive cones.

But by far the richest growth of the coal age was the fern plants—ferns in hundreds of varieties and in such profusion that the Pennsylvanian period is known as the Age of Ferns. No one can conceive of how opulently they grew until he has visited a coal mine and seen their delicate leafy imprints dotting the roofs of its passageways for mile upon wonderful mile. Their lacy outlines in black carbon stand out in bold relief against the gray background of the shales in which they are embedded. These ferns, all with the

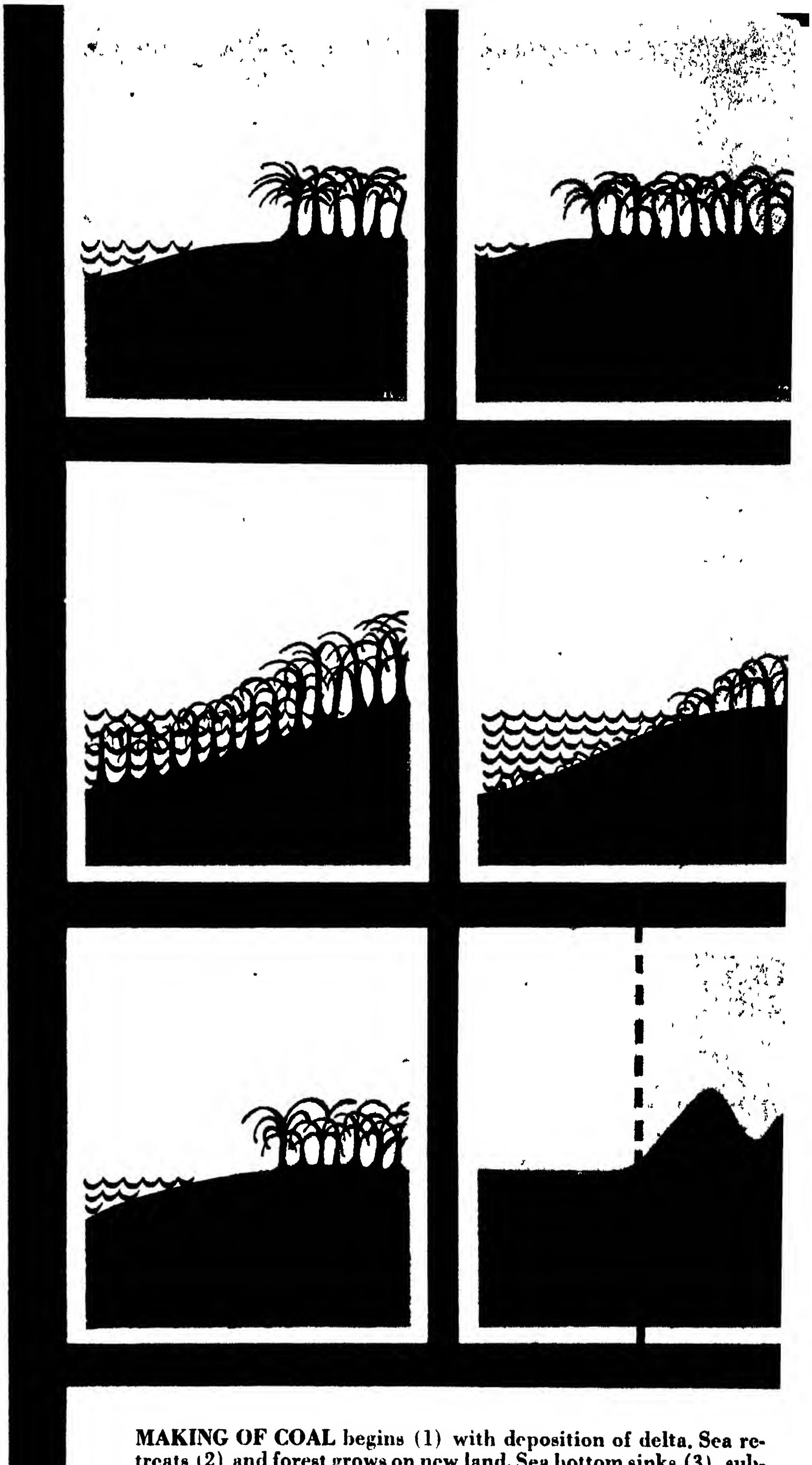
characteristic finely divided fronds of their kind, appear in shapes now no longer seen on earth, some as herbaceous forms, some as scramblers or vines that clothed the forest trees in lacy negligee, some as trees themselves, soaring to a height of 70 feet.

Strictly speaking, they were not all true ferns, although until very recently they were considered so. Microscopic examination of their stem structures has shown that, unlike modern ferns, which without exception reproduce by spores borne on the undersides of the leaflets, a majority of these ancient ferns bore nutlike seeds attached to the fronds. They have therefore been given the name *Cycadofilicales*, or seed ferns. How strange it is that nuts, which today grow only on trees, a quarter of a billion years ago were borne only on ferns! The seed ferns did not outlive the coal age and are now utterly extinct, but the true ferns have come down in unbroken succession through all the changes of the earth's geological history.

THE flora of the great coal age in general resemble the plants now found in the tropics more than they do those in other regions. Moreover, the trees of that period did not have growth rings in their trunks, which indicates that they developed under more or less uniform growing conditions, without great changes in the seasons. These plants are found in coal beds all over the earth, even in the Arctic and Antarctic regions. Does this mean that most of the world had a tropical climate in those days? Perhaps so, but there are some puzzling anomalies to explain. Even if the polar regions had been warm enough to tolerate tropical plants, their poverty of sunlight during half the year would hardly have permitted the lushness and sustained growth of vegetation required to form coal beds. Science may have to find an explanation other than tropical climate for the arctic coal beds. There is a suggestion of a possible answer in recent geological studies which indicate that the earth's great continental masses have shifted bodily in position since the coal strata were formed. If true, this suggests a much less stable earth than many geologists care to admit; but it would account for the presence of extensive coal beds in the Arctic and Antarctic. In any case, here is a challenging problem for study and solution.

The vast realm of plants that lies buried below the surface as coal is the foundation of our modern industrial world. Without the use of coal, medieval conditions would still prevail. Long after our reserves of oil, gas and other strategic mineral resources have been depleted, coal will still remain a most important resource.

Raymond E. Janssen is associate professor of geology at Marshall College in Huntington, W. Va.



MAKING OF COAL begins (1) with deposition of delta. Sea retreats (2) and forest grows on new land. Sea bottom sinks (3), submerging forest. Second delta is laid down over first (4). Process is repeated many times (5), peat hardening into coal. Entire region is then elevated (6). Most coal is bituminous and lower grades, but folding of strata (*right of dotted line*) produces anthracite.

THE PHILIPS AIR ENGINE

The renascence of a forgotten idea has presented our technology with a remarkable new prime mover. Its main advantages: efficiency and independence of special fuels

by Leonard Engel

PROWLING around an industrial fair at Munich in 1937, an engineer of Holland's famous Philips electrical firm discovered a curiosity. It was an old-fashioned Stirling air engine—a 19th-century invention which had been all but forgotten in the high-powered 20th. The engineer found the contraption rather interesting; he thought it might even solve a problem—supplying power for small radio transmitters in isolated areas—with which the Philips firm was at the time much concerned.

Philips' engineers began to analyze the machine. Soon they decided that it had more interesting possibilities than they had thought at first. Essentially it needed only redesigning with modern materials, they concluded, to become a remarkably efficient engine. They went immediately to work, and became so excited about their project that they continued it in secret throughout the German occupation of the Netherlands. Since the end of the war, development of their machine, which is now known as the Philips air engine, has proceeded rapidly. More than 25 laboratory and test models have been built at the Philips Physical Research Laboratory in Eindhoven and additional development work is under way in the U.S. and England. By now the air engine has evoked wide interest among engineers on both sides of the Atlantic. Some enthusiasts compare its renascence with the discovery of the steam engine and the internal combustion engine. Indeed, its performance so far indicates that for many purposes the air engine may be superior to both.

The air engine is an external combustion machine like the steam engine, with air instead of steam as the working medium. Air is alternately heated and cooled to drive a piston. The engine can be designed to run on almost anything that burns, including bituminous coal—an important consideration in these days of almost insatiable demand for high-grade fuels. Built of ordinary metals, and with very few moving parts, it is as compact as a gasoline engine but far quieter. And its efficiency (*i.e.*, the proportion of fuel energy converted into mechanical energy) may ultimately exceed 30 per cent. This figure is better than that attained by comparable gasoline engines at any time and better than that of a Diesel engine under any operating condition except full load.

The air engine has drawbacks that disqualify it for some jobs. But it is so simple and economical in operation that many engineers consider it in general a very satisfactory answer to technology's long quest for a quiet, efficient, trouble-free motor. They think it will soon rank as one of the major "prime movers." The Philips engineers are confident that within a few years they will turn out practical air engines for a variety of uses, with speeds of up to 3,000 revolutions per minute and power outputs of one to several hundred horsepower.

The importance of this development may be gauged by the fact that only four other basic engine types have evolved since the age of power began. It was in 1698 that the Englishman Thomas Savery built the first working steam engine, which James Watt and his contemporaries were to translate into a practical machine in the following century. The idea of the internal combustion engine was born in the fertile brain of the Dutch astronomer and telescope maker Christian Huygens, who in 1680 suggested a power plant run by gunpowder explosions. Huygens' scheme did not work out, but it started a train of thought that led in 1820 to the building by an Englishman named W. Cecil of a machine operated on an explosive mixture of hydrogen and air, and thence to the modern gasoline engine a half century later. The two other basic prime movers are more recent: the steam turbine (based on the same principle as a windmill, with steam substituted for wind as the motive power) was developed in the 1880s, and the gas turbine, which uses hot gases instead of steam, has been perfected in the last decade.

THE AIR ENGINE has been known in principle for nearly two centuries but, like many good ideas in science and technology, it has suffered a long lag in application. The Stirling engine was designed more than a century ago by a Church of Scotland minister named Robert Stirling and his brother James. Their machine even reached the stage of commercial production. It was clumsy and inefficient, however, and the Stirling engine lingered on into the 20th century only as a laboratory motor and as a toy.

The air engine operates on the classical principle underlying all heat engines, which was formulated a century and a quarter ago by the brilliant young French engineer Sadi Carnot. Carnot's principle was roughly this: if a cold gas is compressed and heated and then allowed to expand again to its original pressure, the heat imparted to the gas can be converted to mechanical energy by permitting the gas to expand against a piston or through a turbine. The efficiency of this process depends not on the gas used but on the difference between the maximum and minimum temperatures. Thus it makes no difference in theory what gas is employed; air will do about as well as any.

In the air engine, air is cycled back and forth in a closed circuit within a cylinder. Heat is supplied by a burner fitted over one end of the cylinder. The cycle has four overlapping stages: 1) the air is compressed in a "cold space" at the cool end of the cylinder; 2) it is moved to a "hot space" at the other end and heated to high temperature; 3) it is expanded against a piston; 4) it is cooled and returned to the cold space, where it is recompressed. Then the cycle begins anew

During the cycle, the pressure of the air varies by a ratio of something more than two to one This is low in comparison with other engines and one might imagine that the air engine, while theoretically efficient, would actually develop little power. However, its power output can be raised to a level comparable with that of other engines by increasing the pressure of the air within the cylinder. In one Philips engine the minimum pressure is 22 atmospheres (308 pounds per square inch) and the maximum is 50 atmospheres (700 pounds per square inch).

As in other heat engines, many different mechanical arrangements are possible. Philips has already developed four distinct types of air engine. One is a single-cylinder model illustrated at the right. Another has four cylinders arranged in a square. Still another, a four-cylinder V with a projected output of 300 horsepower, is under construction in Holland.

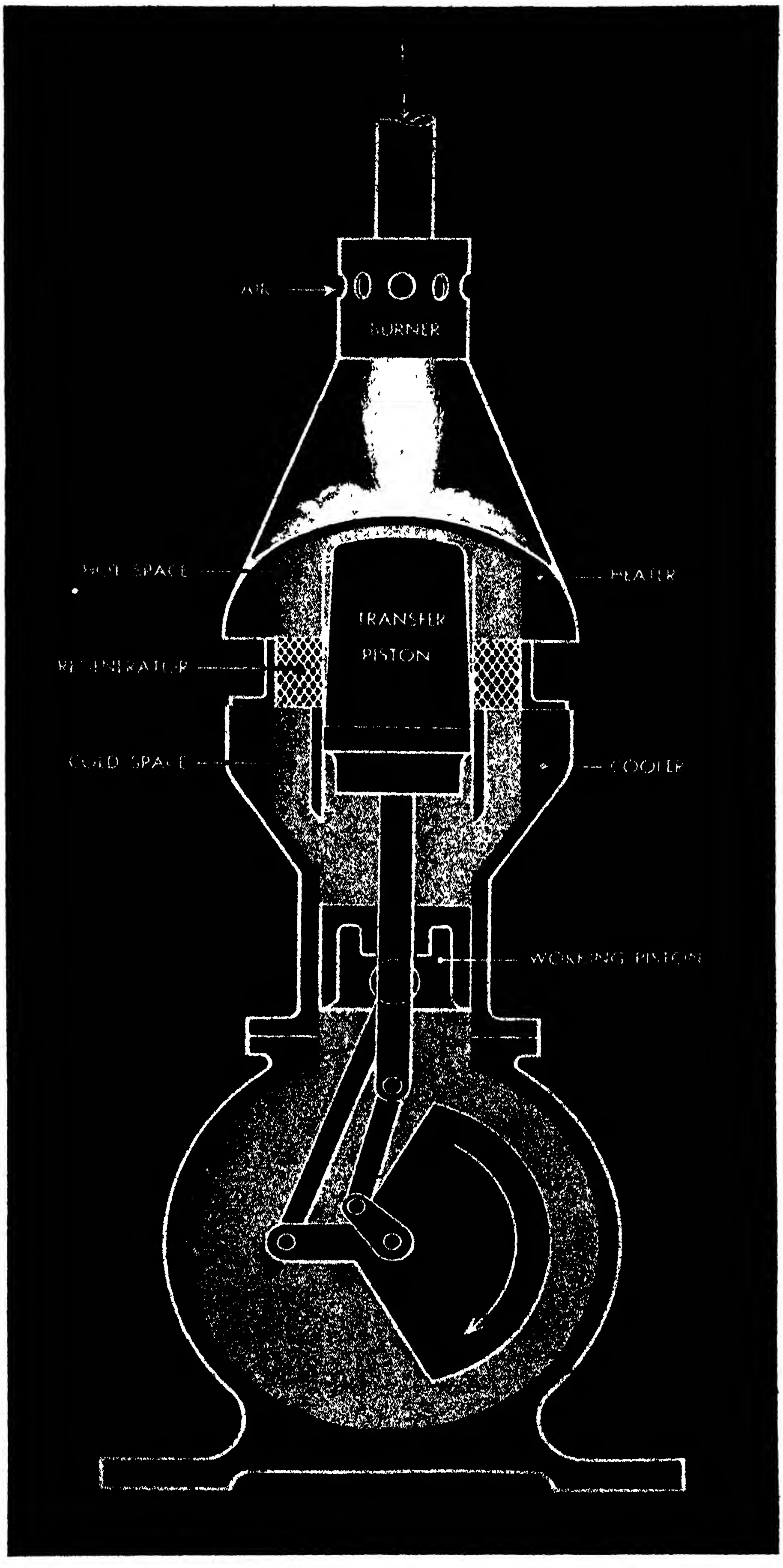
Common to all models is a critically important device known as the "regenerator," situated between the hot and cold ends of the cylinder. This device is a

heat exchanger which absorbs unspent heat from the expanded air as it leaves the hot space and gives the heat back when the air returns. Thus the machine conserves heat and uses it again and again. Only one fourth of the heat imparted to the air during any one cycle is supplied by the burner; three quarters is unspent heat from previous cycles, transferred by the regenerator. Without regeneration fuel consumption would rise by a factor of four and the air engine would be impossibly uneconomical.

Regeneration is, of course, widely employed in other prime movers. Steam engines and steam turbines, for example, use waste heat to raise the temperature of incoming water, and in several types of gas turbine, the combustion air is preheated in a similar manner. Regeneration is also utilized in high-temperature chemical processes and in the blast furnace to heat air for the blast. It is an interesting fact that it was the Stirling brothers who invented the regenerator (or "economizer," as they called it). The Stirling engine also incorporated a surprising number of other modern engineering features.

THE chief improvements in the Philips engine are not in basic design but in materials. Yet all of these materials are readily available. There are no special high-temperature alloys such as are required for gas-turbine blades. The heater, which constitutes the "radiator" for conducting heat from the burner to the engine's charge of air, and other parts exposed to the hot air are fabricated from nonscaling stainless steel. The heater's fins are of aluminum bronze. Other parts, such as pistons and connecting rods, are of standard metals. Contemporary materials, however, are so much superior to those of the last century that even commonplace metals have effected extraordinary improvements in performance. The Stirling engine, which was limited to low temperatures and pressures, weighed 880 pounds per horsepower and had an overall efficiency of three per cent. The Philips machines, which develop peak pressures of 50 atmospheres and hot-space temperatures of 1,350 degrees F., weigh 10 to 20 pounds per horsepower, and production models can be made lighter still.

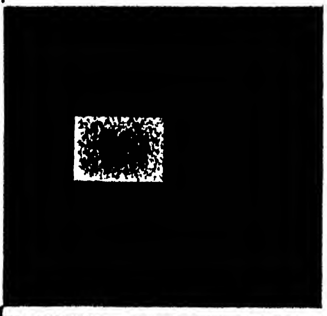
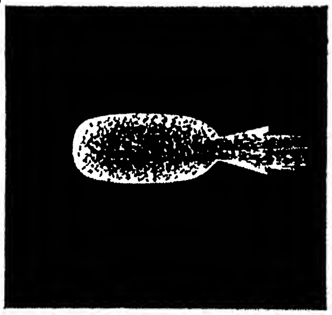
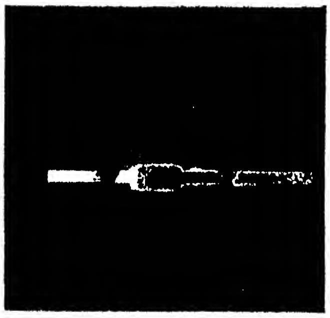
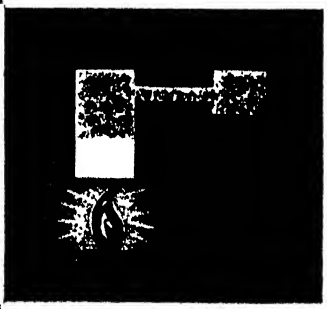
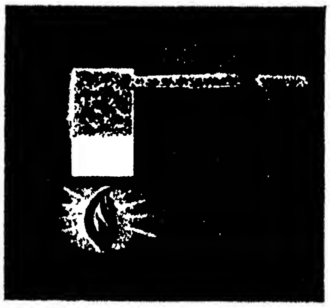
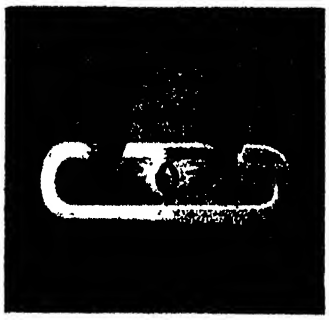
A particularly striking example of the gains brought by modern metals is afforded by the regenerator. In the Stirling engine, the regenerator consisted of a series of closely spaced thin iron plates. This arrangement had too little surface area for rapid heat transfer and the plates so impeded the flow of air that the regenerator was often left out. In the Philips engine, a coil of fine steel wire, crimped to expose more surface, takes the place of the iron plates. The wire coil is a heat-transfer agent of astonishing effectiveness. It heats the air flowing through it from 250 degrees F. to 1,100



THE AIR ENGINE has an unusual but simple principle of operation. Heat is applied outside the engine by burner (*top*). Air in "hot space" is heated, pushing working piston downward to rotate crankshaft (*bottom*). Working piston merely helps displace air. Cycle of operation is depicted on page 55.

A CLASSIFICATION OF HEAT ENGINES

The air engine has a unique place among the devices designed to obtain mechanical energy from heat. In this chart the heat engines have been considerably simplified to show their fundamental principles of operation. The application of heat is indicated by red areas. In many heat engines efficiency is cut down because much heat is wasted. Outstanding exceptions are the air engine and the closed cycle gas turbine, which conserve heat by recycling working medium. The two should prove complementary. The air engine is most efficient at low horsepower, the closed cycle turbine at high horsepower.

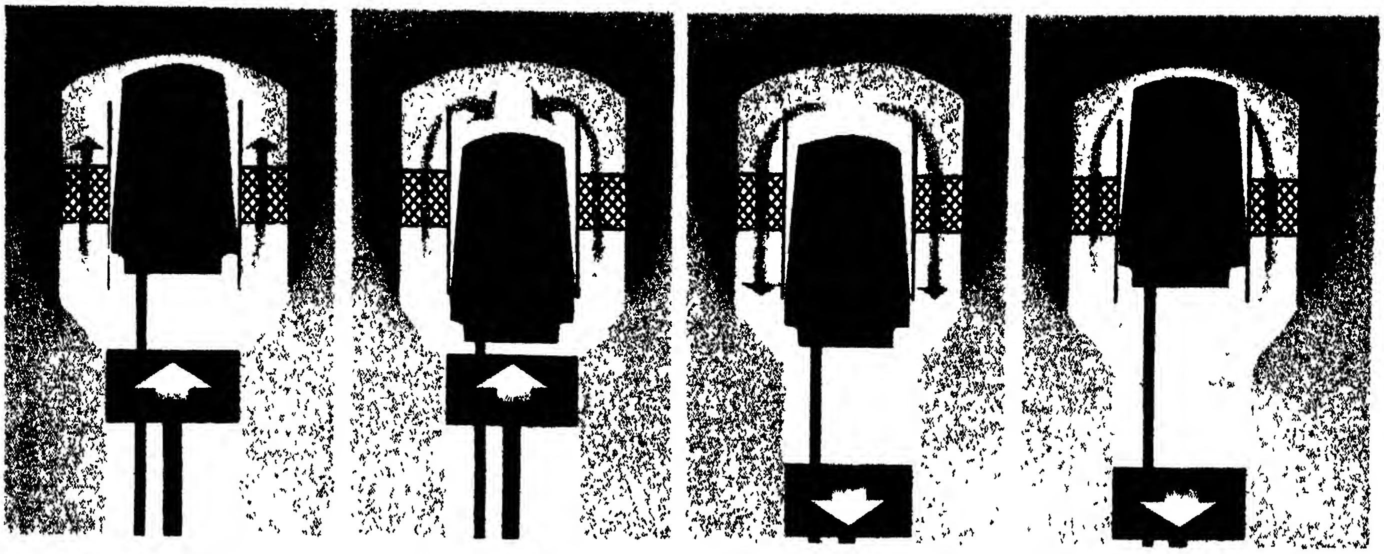
Method of heat transfer	PISTON ENGINES	PISTONLESS ENGINES
DIRECT, without oxygen from air		
DIRECT, with oxygen from air		
INDIRECT, working medium in two phases		
INDIRECT, working medium in one phase		

degrees and then cools it again to 250 degrees—and it accomplishes this no less than 3,000 times a minute.

The single-cylinder Philips engine utilizes a transfer piston, an especially ingenious feature of the Stirling engine. In single-cylinder air engines, it is necessary to have two pistons: one to move air from the cold space to the hot, and the other to move it back. Theoretically, both of these pistons would have to operate under pressure, since the first piston would serve to compress the cold air and the second would take up the expansion of the heated air. Such an arrangement, however, would introduce large friction losses, for the pistons must be fitted tightly to prevent the leakage of air. Two pistons working under pressure in a single cylinder would be impractical. The problem is dealt with by making one of the pistons merely a transfer piston, *i.e.*, one which displaces the charge of air from one space to the other, and by using the second piston for both pressure strokes. How this works is shown in the diagram at the top of page 55.

ONE OF THE major attractions of the air engine is that it is inherently simpler and longer-wearing than comparable internal combustion engines. It can be designed so that all wearing parts are at the cold end of the cylinder. By means of an air cooler supplementing the regenerator, the cold end can be kept below the temperature of boiling water. Thus wear due to heat is reduced to a minimum. A second advantage is that, in contrast with the explosive gas expansion in an internal combustion engine, the heated air expands with relative slowness, resulting not only in less wear but in quieter operation. Third, the combustion being external, there is no deposition of carbon on the working parts. Fourth, the air engine has no valves. In most reciprocating engines, valves are required because the cylinders must be opened once during each cycle. In the internal combustion engine, cylinders are opened to receive air and fuel and dispose of the products of combustion; in the steam engine, to receive the charge of steam from the boiler and, after it is spent, exhaust it to the condenser. The air-engine cylinder, on the other hand, needs no valves because it is a completely enclosed system that requires no intake of air or fuel, and the movement of air within the system is entirely controlled by the pistons.

Multiple-cylinder air engines of large horsepowers can be constructed by assembling single-cylinder engines. However, Philips has worked out an even simpler arrangement that eliminates the transfer piston. In this, there are as many air systems as there are cylinders, but each system consists of the top half of one cylinder as hot space and the bottom half of the next cylinder as cold space; the



SINGLE-CYLINDER air engine requires two pistons. In first drawing working piston (*bottom*) pushes air up into hot space (*red area*). Air is partly heated by passing through wire regenerator coil at the sides. Transfer piston (*top*) then moves down, pushing more cold air into hot space. In third drawing heat expands air, pushing working piston downward. Cycle is completed when transfer piston removes remaining air from hot space.

flow of air, via heater, regenerator and cooler, is between one cylinder and another, not between the top and bottom of each cylinder. When the pistons are made to work in the proper order, the expansion in the top of a cylinder coincides with a cold compression and cold transfer in the bottom half of the same cylinder (though the latter is actually the cold stage of the next air system). Each piston serves simultaneously as working piston and compression-and-transfer piston. The engine therefore has only one piston for each cylinder, which seems as simple a design as is possible in a reciprocating engine.

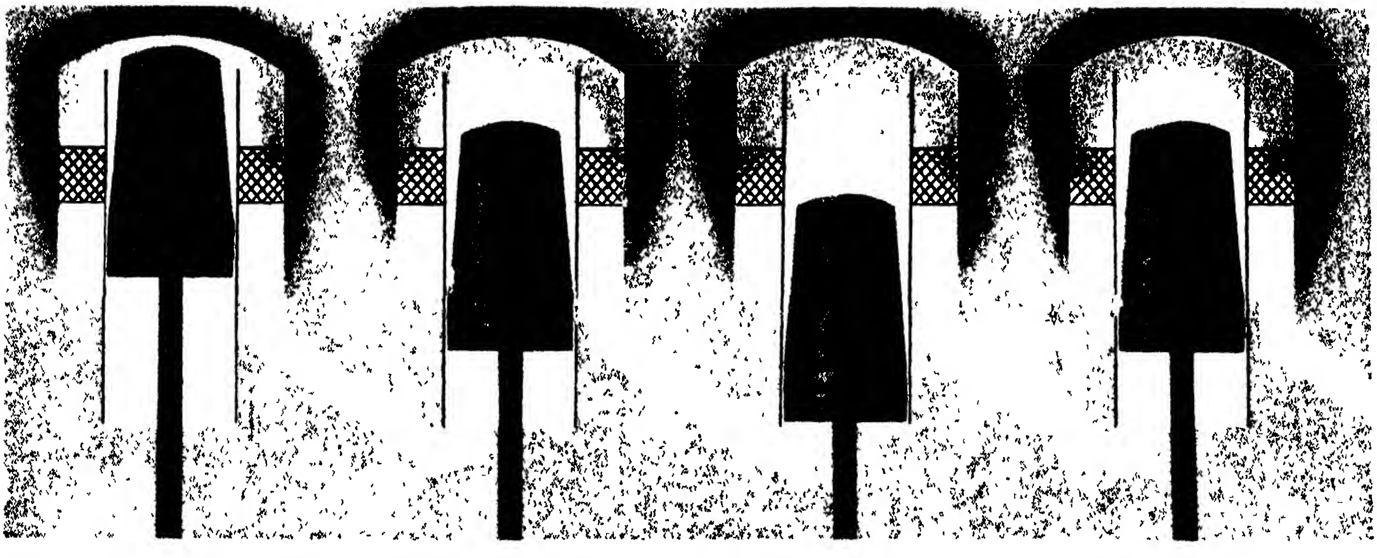
Of the air engine's disadvantages, the most important is the fact that it does not start instantly. Like other external combustion engines, it must be warmed up. This may bar the air engine from many automotive applications. But in some—in farm machinery, for instance—slow starting is not enough of a handicap to nullify the air engine's other advantages. In other fields, such as small power-producing plants, refrigeration plants and small motor ships and boats, where instant starting has no special value, the air engine's ability to operate on low-grade fuels with a minimum of maintenance and repair should prove decisive.

The air engine's independence of liquid fuels gives it a great advantage over internal combustion engines and over most versions of the new gas turbine. Gas turbines usually require liquid fuels because the turbine wheel is spun by combustion gases. An effort has been made to adapt some gas turbines to powdered coal, but no practical success has yet been attained.

Another kind of air engine now under test is the Swiss Ackeret-Keller turbine, an external combustion engine which has a cycle exactly like that of the air engine except that a turbine replaces the piston. Air passes successively through a compressor, a regenerator, an "air boiler," the turbine, and finally through the regenerator and a cooler back to the starting point. The Ackeret-Keller turbine operates on any fuel and promises a thermal efficiency higher than that of the steam turbine.

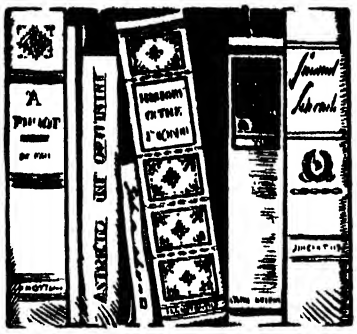
Thus it appears that in the near future air engines may be available throughout the whole span of the horsepower spectrum: Ackeret-Keller air turbines in the high horsepowers where turbines are preferable, and Philips air engines at low and medium horsepowers where reciprocating engines are the most efficient prime movers.

Leonard Engel is a writer of articles on scientific and other topics.



MULTI-CYLINDER engine requires only one piston in each cylinder instead of two. Each piston becomes a combined working piston and transfer piston. Cylinders are connected so that bottom of each piston pushes air into the hot space of the next cylinder. The top of each piston is pushed down by expanding air in the hot space. All pistons are connected in this manner, but h— connection of piston at far left has been omit

THE AGING NEWTON was "the recipient of honors and good fortune of every description. He . . . became a counselor to young scientists, grew rich and philanthropic and was knighted by Queen Anne. . . ." The portrait from which this contemporary engraving was made was painted by Sir Godfrey Kneller, the noted artist.



BOOKS

A fine collection of essays about Isaac Newton, both the man and his accomplishments, on the occasion of his tercentenary

by James R. Newman

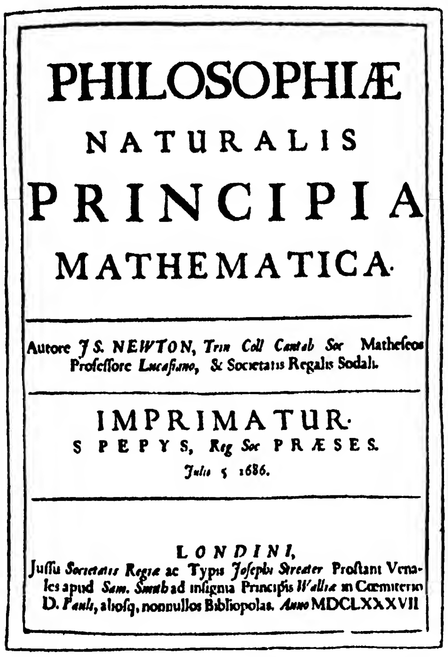
ON Christmas day, 1642, in the year when Galileo died, there was born in the Manor House of Woolsthorpe-by-Colsterworth a male infant, so tiny that, as his mother told him in later years, he might have been put into a quart mug, so frail that he had to wear "a bolster around his neck to support his head." This unfortunate creature was, the parish register reads, "Isaac, sonne of Isaac and Hanna Newton." There is no record that wise men honored the occasion, yet the child was father to a man who altered the thought and habit of the world.

The English Royal Society, over which Isaac Newton presided for almost a quarter century, planned to celebrate the tercentenary of his birth in 1942 (Strangely, this was to be the first international event in Newton's honor since one that took place during his life, when he was elected a foreign associate of the French Academy of Sciences.) Postponed because of the war, the celebration was finally held at London and Cambridge in July of 1946 With representatives of 35 nations attending, it was an international gathering such as had rarely been convoked even before passports, iron curtains and the congealing effects of security persuaded many a traveler to stay home.

A number of the lectures delivered on the occasion have been collected by the Cambridge University Press in a new book called "Newton's Tercentenary Celebration." This slender, handsomely printed volume is a worthy record of the celebration and a credit to the Press. Among its contributors are Sir Robert Robinson, president of the Royal Society; E. N. da C. Andrade; H. W. Turnbull, and such eminent non-British scientists as Niels Bohr of Denmark and S. I. Vavilov of the U.S.S.R. The tributes here offered to Newton's memory concern various aspects of his work and deal also with the man himself. In every sense it is a fine book with as much meaning for the plain, thoughtful man as for the scientist.

I found of especial interest the introductory lecture by Professor Andrade, a lucid survey of Newton's vast achievements, and the brilliant paper "Newton the Man," prepared by Lord Keynes but delivered, because of his death, by his brother Geoffrey Keynes. Andrade's lecture, without giving new facts, tells Newton's story more gracefully and convincingly than this reviewer has heard it told before; the fragment by Lord Keynes (it was never completed), a fresh appraisal based on unpublished manuscripts and personal papers in his possession, is enriched by the imagination and color which Keynes brought to much of his writing.

It is possible to construct a brief biography from these essays. Newton had a happy, normal childhood with little to foreshadow the flowering of his genius. At 18, having done "well enough at school and badly enough as a farmer," he was sent to Cambridge, where he came under the influence of the mathematician Isaac Barrow. It was Barrow who trained Newton, early recognized his powers and, eight



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore *JS. NEWTON*, *Trin. Coll. Cantab. Soc.* Matheseos Professore *Lucasiano*, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

LONDINI,
Jussu *Societatis Regiæ* ac Typis *Josephi Streater*. Prostant Venales apud *Sam. Smith* ad insignia Principis *Walliæ* in Coemiterio D. *Pauli*, aliosq; nonnullos Bibliopolas. *Anno* MDCLXXXVII.

TITLE PAGE of Newton's great *Principia* also bears name of Pepys, then president of the Royal Society.

years later, voluntarily relinquished his chair in mathematics to his pupil—surely a rare phenomenon in academic life.

By the time he became a "senior sophister" in 1664, Newton had begun to show a deep interest in mathematics and natural philosophy. Still, his university years were not all grind. His expense account shows—besides such items as "magnet, 0-16-0" and "the hist. of the Royal Society, 0-7-0"—more frivolous entries: "at the tavern twice, 0-3-6," "at the tavern several other times, 1-0-0" and even "lost at cards twice, 0-15-0."

In 1665 Newton was back at Woolsthorpe, having been forced by the plague to leave Cambridge. There, in two years of benign solitude, he "laid the foundations of his work in the three great fields with which his name is forever associated—the calculus, the nature of white light, and universal gravitation." It was an incredible achievement. Yet there is little to show how Newton's mind evolved these discoveries other than a few words in a memorandum that he wrote when he was 73: "All this was in the two plague years of 1665 and 1666, for in those days I was in the prime of my age for invention, and minded mathematics and philosophy more than at any time since."

It would be a mistake, of course, to infer that these brilliant conceptions came to Newton's mind suddenly and that nothing in the intellectual life of the time had opened the way for them. The calculus, as he proposed it, was a "correlation of what he [had] learned from Descartes, Wallis and Barrow, combined with his original methods of infinite series and their reversion." It was a wonderful creation but not without forebears. His mechanics of the universe, set forth in the great *Principia*, was the culmination, as he recognized and stated, of the work begun by Copernicus and richly enlarged by Tycho Brahe, Kepler and Galileo. The famous discoveries presented in his *Opticks* were built on only meager foundations laid by earlier scientists. But altogether the preceding period was not so dark nor Newton's illumination so unexpected as is sometimes supposed. Great ideas emerge from the common cauldron of intellectual activity and are rarely cooked up in private kettles from original recipes.

THE book has some interesting observations on the celebrated tale of the falling apple, which, like the account of Galileo's experiments with heavy bodies dropped from the tower of Pisa, has not had a kind reception from modern historians of science. Andrade credits Stukeley's report of a conversation in which the aged Newton said that while he was "thinking of what pull could hold the moon in its path, the fall of the apple put it into his head that it might be the same gravitational pull, suitably diminished by distance, as acted on the apple." This account is more plausible than the one which implies that the mere fall of an apple first suggested the universal principle of

gravitation. Falling apples, after all, are commonplace and one might wonder why they did not suggest gravitation to some earlier scientist.

Newton had both a "horror of controversy" and the related habit of postponing for years publication or even informal disclosure of his results. His mathematical inventions of both the generalized binomial theorem and of the calculus he gave to Barrow in 1669 when he started to lecture at Cambridge, but the manuscript was not published until 1711. This post-

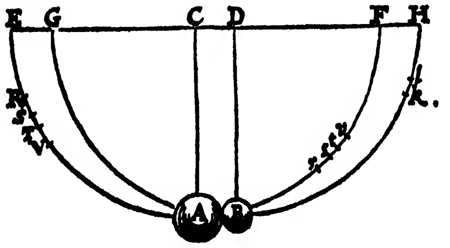


ILLUSTRATION from the *Principia* depicts behavior of moving bodies accelerated in the same direction.

ponement was partly responsible for Newton's famous controversy with Leibnitz over the invention of the calculus.

In 1671 Newton sent Oldenburg, secretary of the Royal Society, an account of his experiments with light: "being in my judgement the oddest, if not the most considerable detection, which hath hitherto been made in the operation of nature." Again, the book itself did not appear until the next century.

THE circumstances surrounding the writing and publication of the *Principia* are elements in the case study of a great man's neuroses. It was characteristic of Newton's temperament to labor in volcanic fits and starts and to alternate his efforts between science, theology and the occult. In 1675, when he was urged to express himself on the subject of planetary motions, it happened, as he said, that he had developed a "great distaste for science." Indeed, one may doubt whether he would have assembled his conclusions and completed his system had he not been, as he wrote, "spurred, cajoled and importuned" by his admirers and his detractors. The grand unifying principle of gravitation occurred to him, as I have mentioned, in his meditations at Woolsthorpe. During the ensuing years he had repeatedly returned to the problem of explaining the motions of the physical universe, but for various reasons he had not forced his mind to the summit. His disinclination to pursue the matter beyond writing a little book, *De Motu Corporum*, is expressed in a letter to Robert Hooke in 1679. "But yet my affection to philosophy [*i.e.*, science] being worn out so that I am almost as little concerned about it as one tradesman uses to be about another man's trade or a countryman about learning, I must acknowledge myself averse from spending the time in writing about it which I think I can spend otherwise more to my own content and to the good of others: and I hope neither you nor anybody else will blame for this averseness."

It was not for this averseness that Newton was blamed. Instead, Hooke, having independently concluded that the motion of the planets could be explained on the basis of an inverse square law of attraction, was furious when the *Principia* appeared with his name not even mentioned in the preface. Newton, vexed beyond bounds by Hooke's contentiousness, threatened, as Andrade says, "to suppress the third book of the *Principia* which is the crown of the work and contains the celestial mechanics." It was the occasion for Newton's famous lament: "Philosophy is such an impertinently litigous lady, that a man had as good be engaged in lawsuits, as to have to do with her."

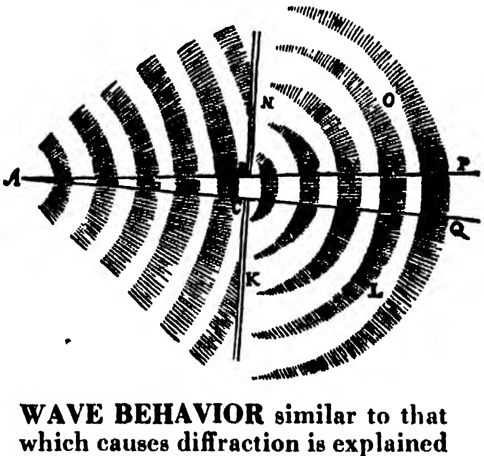
Despite the bitter controversy, there emerged unscathed what remains to modern times the supreme scientific creation, "preëminent," Laplace said, "above any other production of human genius." Nor has time altered this judgment. Einstein, referring to the *Principia*, has said that to Newton nature was "an open book, whose letters he could read without effort." The late Sir Arthur Eddington, answering those who with the coming of relativity would reduce Newton's status to that of an honored relic, wrote: "To suppose that Newton's great scientific reputation is tossing up and down on these latter-day revolutions is to confuse science with omniscience."

The first book of the *Principia* deduces the laws of simple orbits, those already set forth by Kepler, from the "vast generalization that every mass point attracts every other mass point" according to the law of inverse squares. (From this it follows directly that the path of each planet is an ellipse.) It gives also the complete laws of impact of two bodies. The second book treats of "motion in a resisting medium" and tackles the complex problems of the motion of fluids. Hear Newton's words ("like the third movement of a supreme symphony . . . with a recapitulation of previous themes and short statement of the new theme") as he opens the third book:

"In the preceding books I have laid down the principles of philosophy; principles not philosophical but mathematical. . . . These principles are, the laws and conditions of certain motions, and powers or forces, which chiefly have respect to philosophy. But lest they should have appeared of themselves dry and barren, I have illustrated them here and there, with some philosophical scholiums, giving an account of such things . . . as the density and resistance of bodies, spaces void of all bodies, and the motion of light and sounds. It remains, that from the same principles, I now demonstrate the frame of the System of the World."

In the third book, as outlined by Andrade in a formidable list, are established the motions of the planets; the masses of the sun and of the planets which have satellites (a feat which Adam Smith considered to be "above the reach of human reason and experience"); the density of the earth, estimated at "between five and six times that of water" (the accepted figure today is 5.5); the conical motion of the earth's axis (the precession of the equinoxes); the foundation for the theory of tides; the orbits of the comets; the irregularities of the moon's motion due to the pull of the sun; and "the flattened figure of the earth."

The *Principia* is a difficult work, written in a style of "glacial remoteness," without concession to the reader, in the aloof manner of "a high priest." This fact was recognized by Newton. "Upon this subject," he wrote, "I had, indeed, composed the third book in a popular method, that it might be read by many, but afterwards, considering that such as had not sufficiently entered into the principles could not easily discern the strength of the consequences, nor lay aside the prejudices to which they had been many years accustomed, therefore, to prevent the disputes which might be raised upon such accounts, I chose to reduce the substance of this Book into the form of Propositions (in the mathematical way), which should be read by those only who had first made themselves masters of the principles established in the preceding Books: not that I would advise anyone to the previous study



WAVE BEHAVIOR similar to that which causes diffraction is explained in cut for passage in the *Principia.*

of every Proposition of those Books; for they abound with such as might cost too much time, even to readers of good mathematical learning . . ."

WILLIAM WHEWELL, the 19th-century Master of Trinity, expressed well Newton's incomparable talent in the use of geometric methods. "As we read the *Principia*," he wrote, "we feel as when we are in an ancient armoury where the weapons are of gigantic size; and as we

look at them we marvel what manner of man he was who could use as a weapon what we can scarcely lift as a burden."

With the completion of the *Principia* Newton's consuming interest in science was spent. Political and other distractions now claimed him. As an M.P. for Cambridge there is, to be sure, no evidence that he made a splash. (There is an anecdote, perhaps apocryphal, to the effect that his only recorded utterance in Parliament was to ask that a functionary close a window which was causing a draft.) But after he had fallen into a period of "melancholy" and prolonged sleeplessness, when he lost, as he said, "the former consistency" of his mind, he recuperated fully to take on the post of Warden, and later, Master of the Mint. Though a lucrative post, this was not a sinecure, and he found his time occupied in the details of developing a new coinage system.

More than 30 years remained to him during which he was the recipient of honors and good fortune of every description. He supervised new editions of his works, became a counselor and patron to young scientists, grew rich and philanthropic and was knighted by Queen Anne, an honor, Andrade says, that had never before been conferred for services to science. In the warmth of adulation he relaxed his reserve, if not to the point of affability at least to the extent of a ready graciousness and seignorial benevolence; he even reminisced more or less freely for the benefit of contemporary biographers and raconteurs. When Newton died in his 85th year, his body lay in state in the Jerusalem Chamber of Westminster Abbey and none less than the Lord High Chancellor, two dukes and three earls carried his pall. This, Andrade remarks, "meant something in those days."

This is a bare synopsis of Newton's life and work. What about the man himself, in appearance and temper? Newton was of medium height, "exceptionally well set," with abundant hair that turned gray at 30 and silver white in later years. Two portraits reproduced in this volume show him as a strikingly handsome man. In later life he grew a trifle heavy and pink-faced. "When he rode in his coach," says a contemporary, "one arm would be out of his coach on one side and the other on the other"; with his peruke off he was "a venerable sight."

His working and sleeping habits were irregular but this did not seem to impair his health, which, save for rare intervals, was excellent. While he wrote the *Principia*, being then in the mood both for his theoretical inquiries and for experiments in chemistry and alchemy, the fire in his "elaboratory" scarcely went out for six weeks at a time. Only superlatives serve to describe his thunderbolts of insight. A problem set by the eminent Bernoulli as a challenge to "the acutest mathematicians in the world" came to him one afternoon by post and he solved it before going to bed. In 1716, when Leibnitz presented a problem "for the purpose of feeling the pulse of the English analysts," it was also solved by Newton in a few hours. Repeatedly Newton, as Augustus De Morgan once wrote, seemed "to know more than he could possibly have any means of proving." Halley once asked Newton how he knew and whether he had proved a certain discovery about planetary motion

NEWTON'S TOMB is in England's Westminster Abbey. He died on March 20, 1727, at the ripe age of 85.

which Newton had just imparted to him. "Newton was taken aback—'Why, I've known it for years,' he replied. 'If you'll give me a few days, I'll certainly find you a proof of it'—and in due course he did." Asked how he made his discoveries, he once said, "By always thinking unto them" and again, "I keep the subject constantly before me and wait till the first dawnings open little by little into the full light."

Newton left behind a mass of unpublished papers: half a million words on alchemy; 1,300,000 words on theology; assorted and voluminous notes and letters. (Some of the material was in the Portsmouth collection acquired at auction by Lord Keynes.) No competent scholar has ever sifted the papers with care. A nervous bishop of the 18th century took one look at the theological manuscripts and put them aside "with horror"; others were equally disinclined to pry.

Even in his brief scrutiny of the unpublished material Keynes gathered insights more acute than those of earlier biographers. The conventional picture of Newton as the supreme rationalist, "one who taught us to think on the lines of cold and untinctured reason," is false. Newton was not, said Keynes, the first man in the age of reason. "He was the last of the magicians, the last of the Babylonians and Sumerians, the last great mind which looked out on the visible and intellectual world with the same eyes as those who began to build our intellectual inheritance rather less than 10,000 years ago." He was also a "profound neurotic." This went far beyond mere shyness, reserve, inwardness and distrust. He cared nothing for women; he found it difficult to give anything of himself, to part with anything he created. Pride of accomplishment and the desire for recognition, both normal, were countered in Newton by a morbid fear of criticism and the neurotic instinct not to reveal his thoughts. It seems clear, and for this we may be thankful, that Newton's inner life was richer by just so much as he was incapable of imparting to others; his meditations were serene and undisturbed because when engaged upon them, for however extended a period, the world around him ceased to exist. This may explain how he was able to perform the feat of keeping the elements of a problem in uninterrupted focus "until he had seen straight through it." As Keynes said, anyone who has tried to concentrate fully upon a problem knows that despite the most intense concentration "it will dissolve and escape."

THOUGH he was master of reason, Newton's deepest instincts were "occult, esoteric, semantic." He looked on the universe, says Keynes, as a riddle. He felt that if he thought long and hard and focused his attention on the clues left by God it would all become clear. He would read the "riddle of the Godhead" as he had read the riddle of heaven and earth. If this explanation suffices for the works for which he is remembered, it will suffice to explain the theological and Hermetic writings which constitute the bulk of his utterances and (since he kept them locked in strong boxes and never consented to disclose their revelations) probably the most precious part of his work.

"I do not know," said Newton shortly before his death, "what I may appear to the world; but to myself I seem to have been only like a boy, playing on the seashore, and diverting myself, in now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me." Despite its orotund style, the comment was probably sincere. Newton was a mixture of scientist and mystic; a flux of contradictory inclinations and diverse powers; a spirit both shining and inscrutable; a mind, in Wordsworth's lines, forever "voyaging through strange seas of thought alone."

James R. Newman is an attorney, visiting lecturer at Yale Law School and by avocation a writer on scientific subjects.

THE AMATEUR

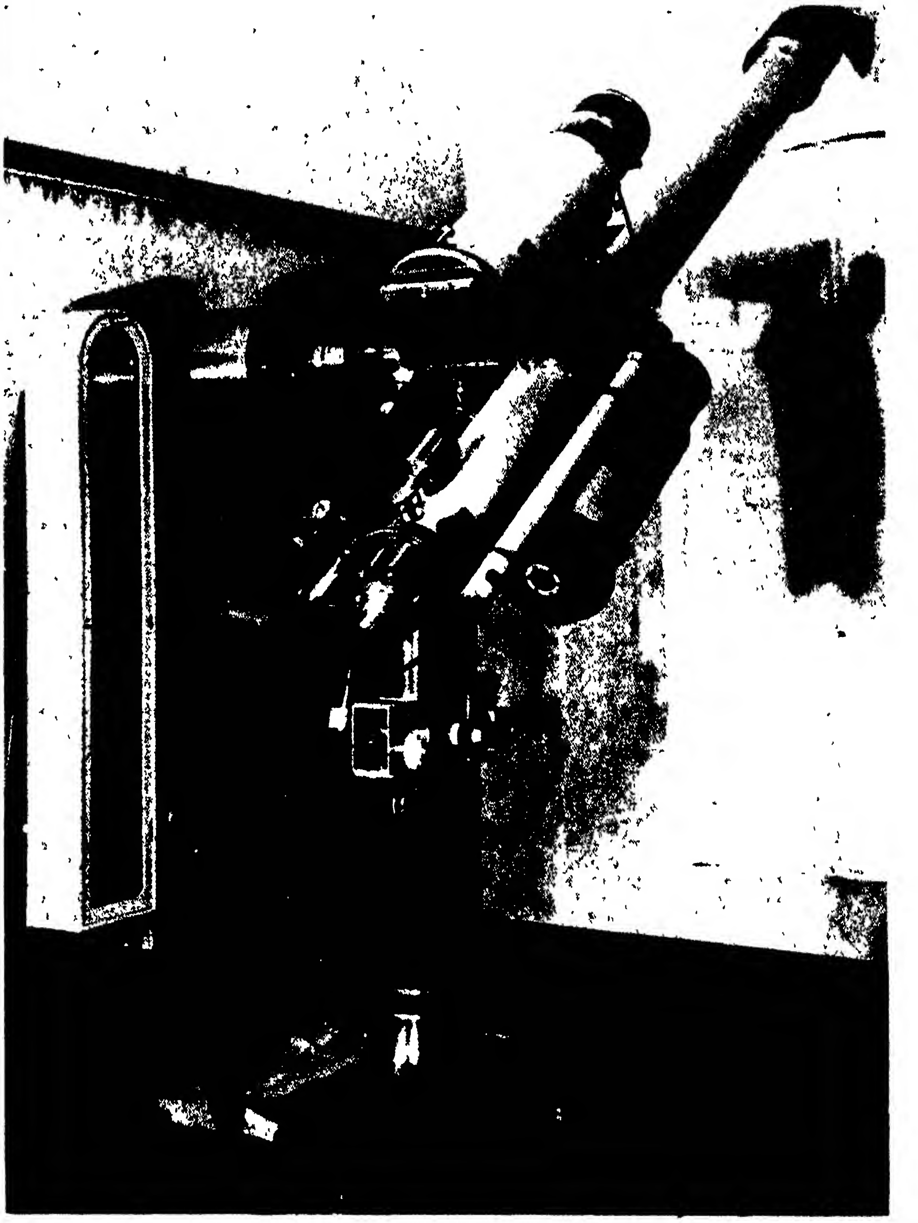
Conducted by Albert G. Ingalls

NOT in the 22 years since the book *Amateur Telescope Making* altered a little-known art into a nationwide hobby has this magazine learned of as finished an amateur's telescope as the one described this month. Since the telescope was made in Scotland this may be a good time to put aside that tiresome boast about "Yankee ingenuity."

If about 170 hours suffice to make a six-inch refractor that is serviceable and satisfactory, what accounts for the 17,000 hours of spare-time work that Robert Louis Waland, a Dumfries aircraft factory employee, gave to this telescope over a period of 11 years? Extras? The answer is yes—two attached star cameras, a drive that was an immense job in itself and a synchronome clock. But mainly it was high standards of design and exquisite workmanship throughout.

Waland began, as is recommended, by making a reflector. On the refractor shown here, which was his next, he was helped by Ellison and Dr. E. A. Baker of the Royal Observatory at Edinburgh and by *Amateur Telescope Making—Advanced.*

The lower part of Waland's telescope pedestal is made of aluminum cast in two



Waland's six-inch refracting telescope with star cameras

ASTRONOMER

parts. The upper part is of steel tubing. These parts and the mounting are blue-gray. The tube and cameras are cream. The upper camera has an $f/4.5$, five-inch photographic doublet lens. The lower one is a 5½-inch Schmidt.

On the right is a two-inch star finder and on the left a little 6× telescope for viewing the illuminated declination circle without leaving the eyepiece; Waland claims he is "lazy"! The eyepiece end has a penta-prism star diagonal and guiding head, hence does not revert the image. Why aren't there more of these?

The synchronome clock shown in the illustration controls an induction motor that runs the drive on the pedestal and this, the job Waland says he is most proud of, cannot here be described for lack of space. He barely mentioned the clock, a type accurate to one second a week, and was asked why. His reply: "It's just an ordinary synchronome I made." He also omitted to mention the optics and was queried: "Where did you buy them?" Reply: "What! And deprive myself of all that pleasure? All optics home-brewed including 11 eyepieces." Perhaps these two full-sized jobs looked minor against a 17,000-hour total.

By accident Dr. Erwin Finlay Freundlich, before Nazi days founder and director of the Einstein Institute ("Einstein Tower") and now at the University of St. Andrews, learned of Waland's telescope. The outcome: Waland is now instrument maker at St. Andrews and is building the University a 30-36-inch Schmidt-Cassegrainian telescope.

Wartime restrictions kept Waland from building an observatory from new materials. But now he has found some second-hand steel and can at last have a private observatory at his new home "Orlington," which is in Priestden Place, St. Andrews, Fife, Scotland.

The remaining description is primarily for telescope makers who wish to study closely the details of this advanced telescope. Waland writes:

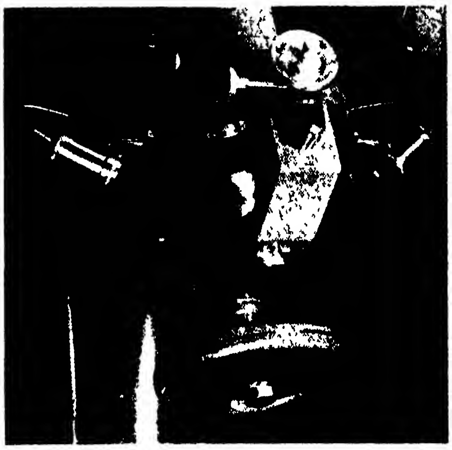
"The axes are made from three-inch heavy seamless steel tubing. The design is such that the 1½-inch inner shafts carry no weight, except in the case of the counterweight. The 'bottleneck' is made from solid steel 3½ inches in diameter.

"The lower end of the polar axis has a handwheel for quick motion in right ascension and an hour circle for direct setting. This circle is free to rotate on the polar axis and is set by the hand knob at the top. The time shown by the indicator on the axis housing corresponds to the sidereal time at the moment. The telescope is then rotated on the polar axis until the lower indicator, which rotates with it (being attached to the inner shaft),

shows the right ascension of the object.

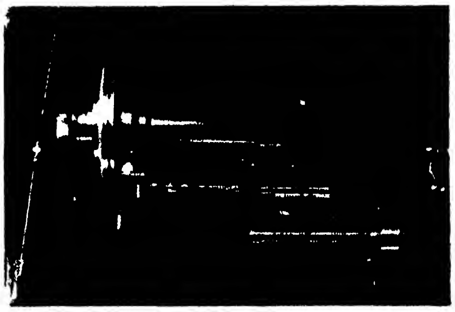
"The worm-wheel drive is totally enclosed and runs in an oil bath. The second worm-wheel reduction connects to the clock by a driving shaft with universal joint at both ends. The worm wheel is not attached directly to the polar axis but is free to rotate on the latter.

"The polar axis is driven by the worm wheel by way of the right ascension clamp,



Lower end of the polar axis

which can be operated from the eyepiece end of the telescope in any position of observation. The gearing seen between the telescope tube and the declination circle transmits the power. The clamp takes the form of a V-shaped pulley attached to the worm wheel and surrounded completely by a V-ring (like a V-belt on a pulley). The ring is clamped by a screw. This screw is operated by two universal joints and a sliding, keyed shaft. This compensates for the slight lack of alignment and varying distance, which results from the operation of the right ascension slow-motion tangential lever. This lever is

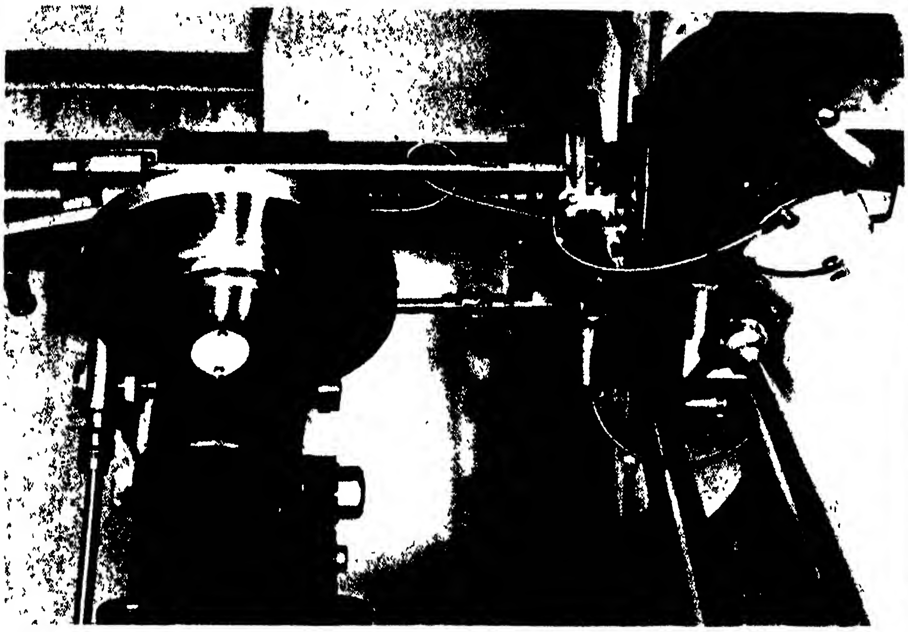


The two axes from below

L-shaped and pivoted where the legs meet, and is also operated by a second set of gears beyond the declination circle. The movement is transmitted through the rod which can be seen running parallel to the declination axis. The end of this lever is seen above the worm housing. This screw motion applied by hand is opposed by a powerful spring operating on the other arm of the lever. This cuts out backlash and its evil effects. The same lever is attached to a V-shaped casting seen below which transmits the motion to the declina-

tion axis by way of the pivot point of the lever, using the clamp also as a pivot. This imparts a rotation to the polar axis and is quite independent of the clock drive."

THROUGHOUT much of the literature of telescope mirror-making the terms parabola and paraboloid are used interchangeably as if the two were synonymous. Of course nearly everybody understands what is meant, a paraboloid being the two-dimensional surface generated when the one-dimensional curve called a parabola is rotated about its axis. The escape from the alleged crime is that when a mirror is called a parabola its cross section is described.



The two axes from above. At right, the telescope tube

What more rightfully rubs the mathematician's whiskers backward is calling the paraboloid a curve. Being two-dimensional, it is a surface. In sum, then:

Parabola: one-dimensional, curve.
Paraboloid: two-dimensional, surface.

WALKDEN of London mentions a wrinkle for observing with his richest-field telescope. In an ordinary straight view where the telescope tube is fixed, as on a mounting, the central 20 degrees of the field may be good and the margins fairly good, until you swivel your eye to get a direct look at them with the central part of the retina. Then they seem strangely dim and also have poor definition.

What you have done, Walkden points out, is to move the crystalline lens of the eye sidewise from the Ramsden circle so only a crescent of the lens and the telescope mirror remain in use. This is because the Ramsden circle is so close to the size of the eye lens; you planned it that way when you designed the telescope.

The wrinkle is simply to compensate this partial eclipse by moving the whole head in the opposite direction an amount which will come to about a seventh of an inch. If the telescope is not on a mounting it can itself be moved a little. The chances are that the average observer does these things unconsciously, but it is instructive to realize what he is doing and why.

COULD a large flat be made by attaching several small flats to a rigid backing and adjusting them to a single plane? Readers who have asked this question will find interest in a report by Professor Arthur Howe Carpenter of La Grange, Ill.

"I made it work," he says. "When I corrected the secondary for my 20½-inch Cassegrainian telescope I needed a flat of the same diameter for use in figuring the secondary. Having three 10-inch flats on hand I silvered them and set them up—the three arranged in triangular fashion—on a heavy, solid backing made of two-by-fours bolted together. Each flat was given its own trio of push-pull adjusting screws. By adjusting first two and then all three flats I brought the star images into coincidence. This was a tedious job. I was helped by a very small defect in the pinhole and later when the secondary was figured I could see that same defect very perfectly with a good eyepiece. It looked exactly as it had by direct inspection with a pocket magnifier.

"Next the convex secondary was mounted in place and tested and corrected in the usual manner.

"Actually the three flats probably did not lie in precisely the same plane, but they did lie in parallel planes, which was as good."

In similar experiments Russell Porter once brought three small flats into a single plane by screw adjustment. "The screws," he says, "were not even delicate, just plain machine screws. By placing a large flat over the three smaller ones it took only a few minutes to contact them with the large one, same color over all three."

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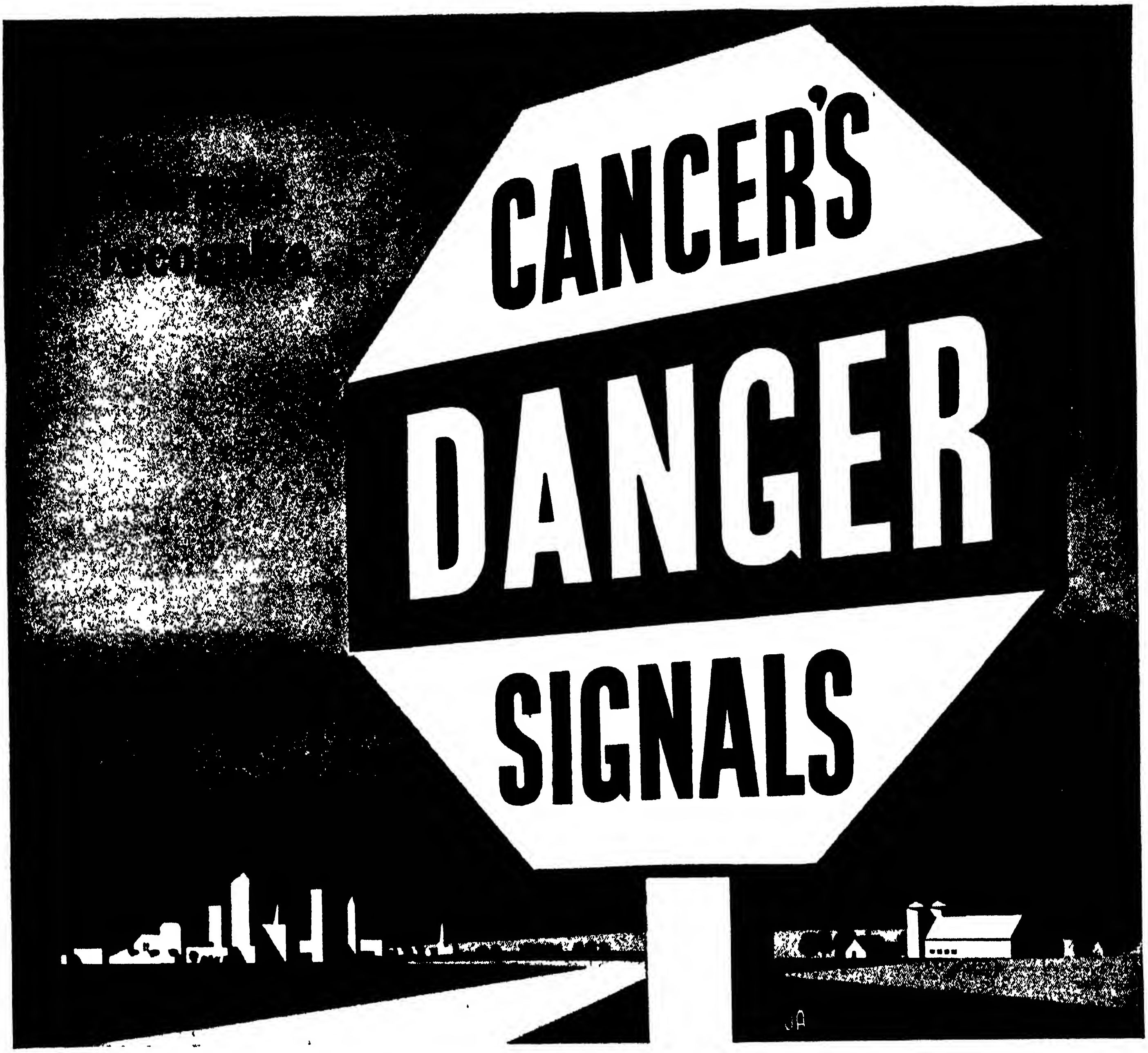
PHOTOSYNTHESIS (PAGE 24)

FIFTY CENTS

August 1948



If you detect any of the following symptoms, see your doctor at once. It may not mean cancer, but if it should, remember that most cases can be cured if treated in time.

1. Any sore that does not heal —particularly about the tongue, mouth or lips. Do not pass it off as "nothing at all." Go to the doctor.

2. A painless lump or thickening, especially in the breast, lip, or tongue. Do not wait "to see what happens." Go to the doctor.

3. Irregular bleeding or discharge from any natural body opening. Do not wait for pain. Go to the doctor.

4. Persistent indigestion. Do not wait for loss of weight. Go to the doctor.

5. Progressive change in the color or size of a wart, mole or birthmark. Don't try salves or ointments. Go to the doctor.

6. Persistent hoarseness, unexplained cough, or difficulty in swallowing. Do not assume that it is due to smoking or some other form of irritation which will clear up. Go to the doctor.

7. Any change in the normal bowel habits. Do not attempt to diagnose yourself. Go to the doctor.

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AMERICAN CANCER SOCIETY
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LETTERS

Sirs:

The lack of interest displayed by many social scientists in the type of mathematical regularity which has built physical science is underlined by two letters in your July issue. Each letter advocates that social problems be approached exclusively in such anthropomorphic and purely verbal terms as "frustration," "misery," "aggression," and "minority groups." Your readers need not be reminded that millions of dollars are spent every month in support of research and instruction limited to such terms. It is significant of the primitive state of their science that your two correspondents evince emotional opposition to even a little investigation of a different sort.

Although with my article, "Concerning 'Social Physics,'" references were given directly and indirectly to a number of related scholarly papers, both letters seem to have been written without examination of them. Mr. Eaton "pointedly" suggests "that the editors of the *Scientific American*, when preparing future articles on social science topics, first secure the views of social scientists," but this is a formality which he himself ignores.

For example, the place which the principle of demographic gravitation now holds in investigations of marketing is shown by a comprehensive study of the United States: "Market Areas for Shopping Lines," published in 1947 by the Curtis Publishing Company. It was prepared by their Research Department with the aid of Professor P. D. Converse. Much thought and labor have been required to apply Newton's laws of mechanics to detailed problems of mechanical engineering. No doubt a variety of obstacles must be overcome before Reilly's law of retail gravitation is fully utilized in the field of marketing, but a good beginning has been made.

Mr. Eaton advocates that we "approach the data of social behavior at their own level and in the terms which they themselves suggest." With this prescription we all can be in complete agreement. The terms which suggest themselves to an investigator familiar with physics may well differ from the conventional ones, and the level he selects for initial treatment will be that of large groups of people rather than of individuals.

Professor Henry objects to population potential as "mysterious." Actually the concept sums up, in a single powerful abstraction, an extensive complex of human processes which when examined separately have nothing mysterious about them. Physicists have learned the usefulness of this sort of abstraction and "mystery." Generalities in natural science are tested by their agreement with the course of phenomena, rather than by prejudgments which spring from philosophical dogmas and whatnot.

Mr. Eaton's statement is devoted wholly to the expression of his own prejudgments. Professor Henry makes only one specific criticism which relates to observed phenomena: his point is well taken that in the formula population divided by distance, an average inhabitant of India or China exhibits a weight much less than that of an average inhabitant of the United States. He is not justified in dismissing the formula on that account. When enough social data are available the "molecular weights" can be determined from the observations.

Because of limitations of space my article had to be confined almost exclusively to conditions in the United States, although even here a refined study uncovers evidence which suggests that Negroes in the Deep South have lower weight than average while people in the eleven Rocky Mountain and West Coast states have higher weight. To find the reasons for these differences will be important.

Sociologists, even demographers, have not attempted to make a systematic study of distance, and number of people, as social factors. Professor Henry wants to dismiss these factors as "mechanistic," and he asserts that their study "distracts attention from the real problems of social living." He is quite right in (unconsciously) implying that much sociological discussion (of the problems he considers "real") treats human beings as disembodied spirits. He is right also in declaring that thinking which is purely mechanistic about human relations may associate itself with tyranny, and I had indicated as much in my own concluding paragraph. But the world has known tyrants for thousands of years; they have used to bolster their positions not exact mechanistic thinking but often irrational slogans purporting to possess spiritual connotations.

For the immediate future I can foresee no serious threat of tyranny in the proposition that economic, social, and cultural welfare are maximized when the total number of effective relations among all individuals is maximized, subject to the inescapable restrictions which space and time and number exert statistically on men. Industrial plant, utilizable natural resources, and monetary funds must be looked upon not as things which operate automatically of themselves, but as a continual re-creation out of human relations.

Detailed statistical support for this point of view is included in a longer paper in the journal *Sociometry* for May. It is hoped that continued study will serve to improve the definition of some such controlling concept as "the public interest" by bringing to bear upon it the principles of social physics. From the vigor of their communications it is evident that both Professor Henry and Mr. Eaton can make contributions of another nature to an improved definition, provided they realize that existing conclusions and methods of sociology- and of physics—are incapable of providing all the answers.

With respect to the first use of the name "social physics", this opportunity is taken to record a remark which the eminent historian of science, Professor George Sarton of Harvard, kindly made in a letter from Switzerland after he read the May issue: namely, that it was introduced before Comte by Quételet, who in 1835 wrote a book with that title.

JOHN Q. STEWART

Randolph, N. H.

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50 AND 100 YEARS AGO

AUGUST 1898. "This week the American Association for the Advancement of Science celebrates the fiftieth anniversary of its existence. In 1847 the American Association of Biologists and Naturalists, which had been formed in 1840 as the Association of American Biologists, met for its annual meeting in Boston. It was then determined to enlarge its scope and broaden its work. This year the Association turns to the place of its birth and meets again in the hospitable precincts of Boston."

"Within a week we have had the synthetic production of albumin demonstrated before a learned body, and within a month 'coronium', which has been supposed to exist only in the sun, has been detected in volcanic gases, and the Italian scientists gravely observe 'that there are probably other new elements in these gases.' In June last, Prof. Ramsay announced the discovery of 'krypton', a new gaseous element existing in the air, and close on its heels come two other elements, also obtained from the atmosphere, which have been named 'neon' and 'metargon.'"

"There is only one thing that can match the splendid heroism of our soldiers at Santiago, and that is the criminal incompetence of the Subsistence and Medical Departments to which the feeding and nursing of these brave fellows was intrusted. There are times when silence is a sin, and we feel that to remain quiet in the presence of a shameful and fatal maladministration that has added to the natural horrors of war others that might easily have been avoided, is to do a positive wrong to the heroes of Guantanamo, El Caney and San Juan."

"It is well known that the production of intoxication by the drinking of ether is a vice especially prevalent among the north and northwest portions of Ireland, that it obtains in some degree in the western counties of England, and also that it sometimes finds its way into the boudoirs of titled and aristocratic dames; but until recently it was held to be strictly confined to the United Kingdom. The medical officer of health for the district of Heydekrug in Lithuanian Prussia draws attention to the fact that ether tippling is excessively prevalent and constantly increasing. The startling, increased and general consumption of substitutes for alcoholic beverages raises again the pertinent question whether the restriction placed upon the sale of absolutely pure products does not work harm rather than good."

"The official report on the production of iron made by the American Iron and Steel Association shows conclusively our pre-eminence in this branch of industry. In the first half of 1898 our output was the largest known, either in the United States or any other country for the same period, and more than half a million tons greater than in any other half year of our existence. Production has increased so as to reach 984,950 tons a month, and the apparent consumption has risen even more, reaching 991,391 tons."

"Excessive loading of the central span of the Brooklyn Bridge, due to a blockage on the roadway, assisted possibly by extreme expansion due to the heat, caused, on the evening of July 29, a buckling of the bottom chords of the four inside stiffening trusses."

AUGUST 1848. "Dr. Robinson lately gave an interesting account, to the Royal Dublin Academy, of Lord Rosse's telescope. Unfavorable weather had prevented much being done with the telescope, but in one good night Dr. Robinson observed in the moon the large flat bottom of the crater covered with fragments, and became satisfied that one of the bright stripes so often discussed had no visible elevation above the general surface. The nebula of Orion, even with the imperfect mirror and in bad nights, was seen to be composed of stars in that part which presents the strange flocculent appearance described by Sir John Herschel. The most remarkable nebular arrangement which the instrument has revealed is that where the stars are grouped in spirals, one of which Lord Rosse described in 1845."

"On one of the southern spurs of the Rocky Mountains, there is a valley full of geological wonders and curiosities, and is at present surrounded with a romantic interest, as being the place where that strange people, the Mormons, have taken up their residence. A portion of them have settled in a valley of California, in which there is a lake of salt water, so salty that it is impossible for a man to sink himself in it above his arm-pits, and after bathing there awhile and drying himself he will be encrusted over. There are also hot springs, boiling hot continually, thus indicating subterranean fires which will one day banish the Mormon from that land by a far fiercer tempest than that enmity which drove them from our midst."

"The foot-way of the Suspension Bridge which spans the gulf of Niagara for a thousand feet, is now completed. Foot passengers now walk across from the dominions of Uncle Sam to the dominions of Aunt Victoria for 25 cents. This is a great work, not only physically but morally. It will promote intercourse and good will among the republicans and royalists. Difference of opinion regarding governments, should never make men enemies."

"Without oxygen animal life would cease to exist. It is the principal supporter of combustion and therefore without it we neither could light a candle nor kindle a fire. The gas is invisible and inodorous, and yet for all this, it is of the most importance and by its various uses, it fulfills the divine allusion to the simple laws of nature 'he has chosen the weak things of this world to confound the mighty.'"

"The celebrated Norwegian violinist Ole Bull is now working as a journeyman in the Manufactory of M. Vuillaume, a Parisian musical instrument maker, in the hope of being enabled to make a violin that shall equal the tones of those made by the celebrated Stradivarius, of Cremona; and for this purpose he has brought from Norway wood more than 200 years old."

"It is an established fact that a lightning conductor in order to fully accomplish the purpose for which it is designed, must have its lower extremity in perfect communication with the earth. The reason is that the electric fluid in passing from one body to another will select for its course that line which will afford it the most direct and perfect communication. Hence a lightning conductor to be effectual must give a free and uninterrupted passage of the fluid to the earth, which cannot in any manner be so well done as by having it terminate in water; that being also a good conductor."

"Professor Morse, the inventor of the electric telegraph, was married on the 10th inst. at Utica, N. Y. to Miss S. Griswold of New Orleans."

THE COVER

The painting on the cover, showing a group of tropical plants, illustrates the lush biological product of photosynthesis (*page 24*). This process is constantly performed by green trees and microscopic diatoms, but it is imperfectly understood by man. In land plants the essential pigment is green chlorophyll. The brilliant red leaves at center and left are the familiar *Caladium*, or ace of hearts; the green at upper right is *Philodendron hastatum*, the small cluster of leaves at bottom center is *Episcia coccinea*, the saw-tooth leaf to the right is *Neoregelia spectabilis* (fingernail plant); small leaves in lower right-hand corner are *Ficus repens* (creeping rubber plant)

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

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10	Emil Lowenstein
11	Farm Home Administration, U.S Department of Agriculture (*top*) Soil Conservation Service, U.S. Department of Agriculture (*bottom*)
12-13	Bob Landry--Pix (*top*), Russell W Porter (*bottom*)
14	California Institute of Technology (*top*), Bob Landry -Pix (*bottom*)
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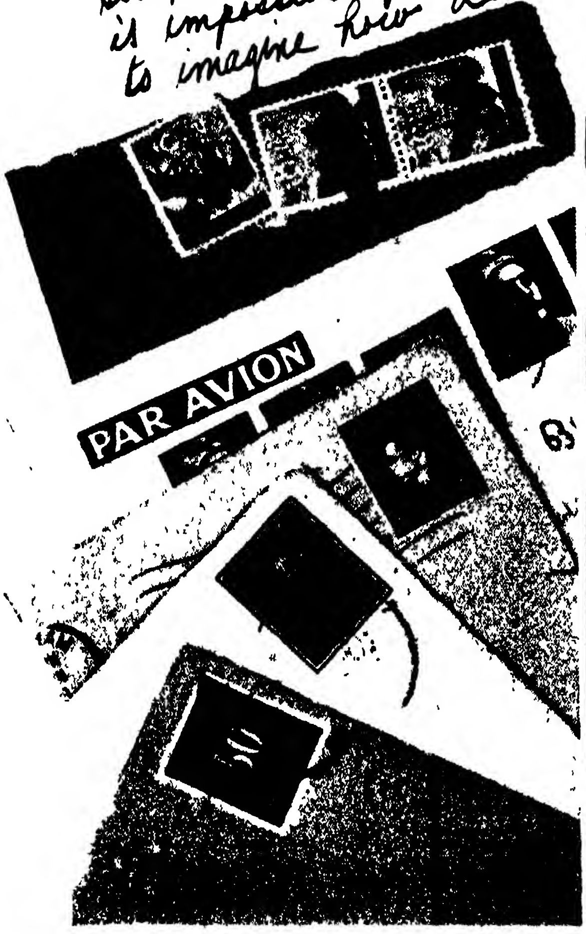

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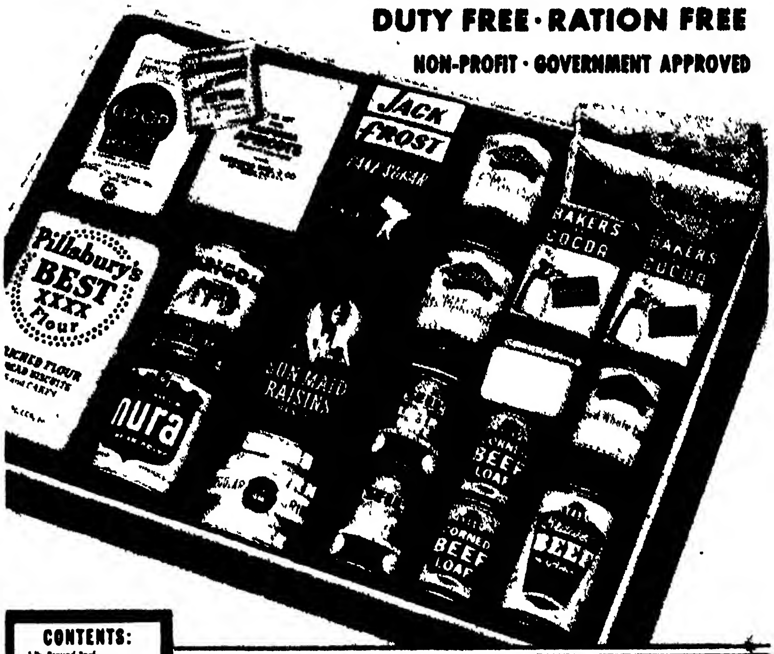

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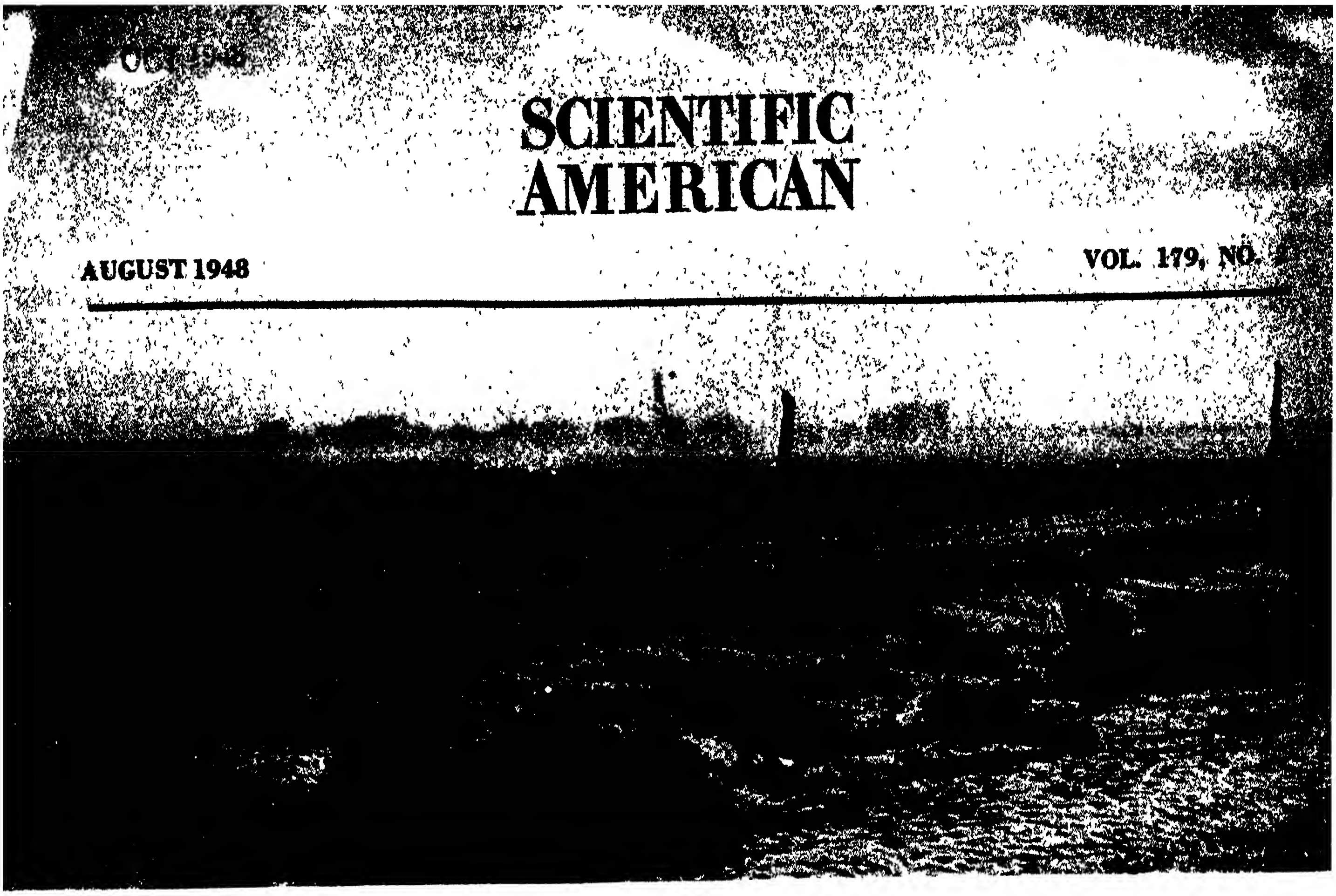


THE LAND BLOWS from the farm of Mrs. Addie Gregory near Causey, N. M. Drifted soil lies in a roadside ditch. Excessive farming of sandy soils, not lack of rain, is the primary cause of dust storms in this area.

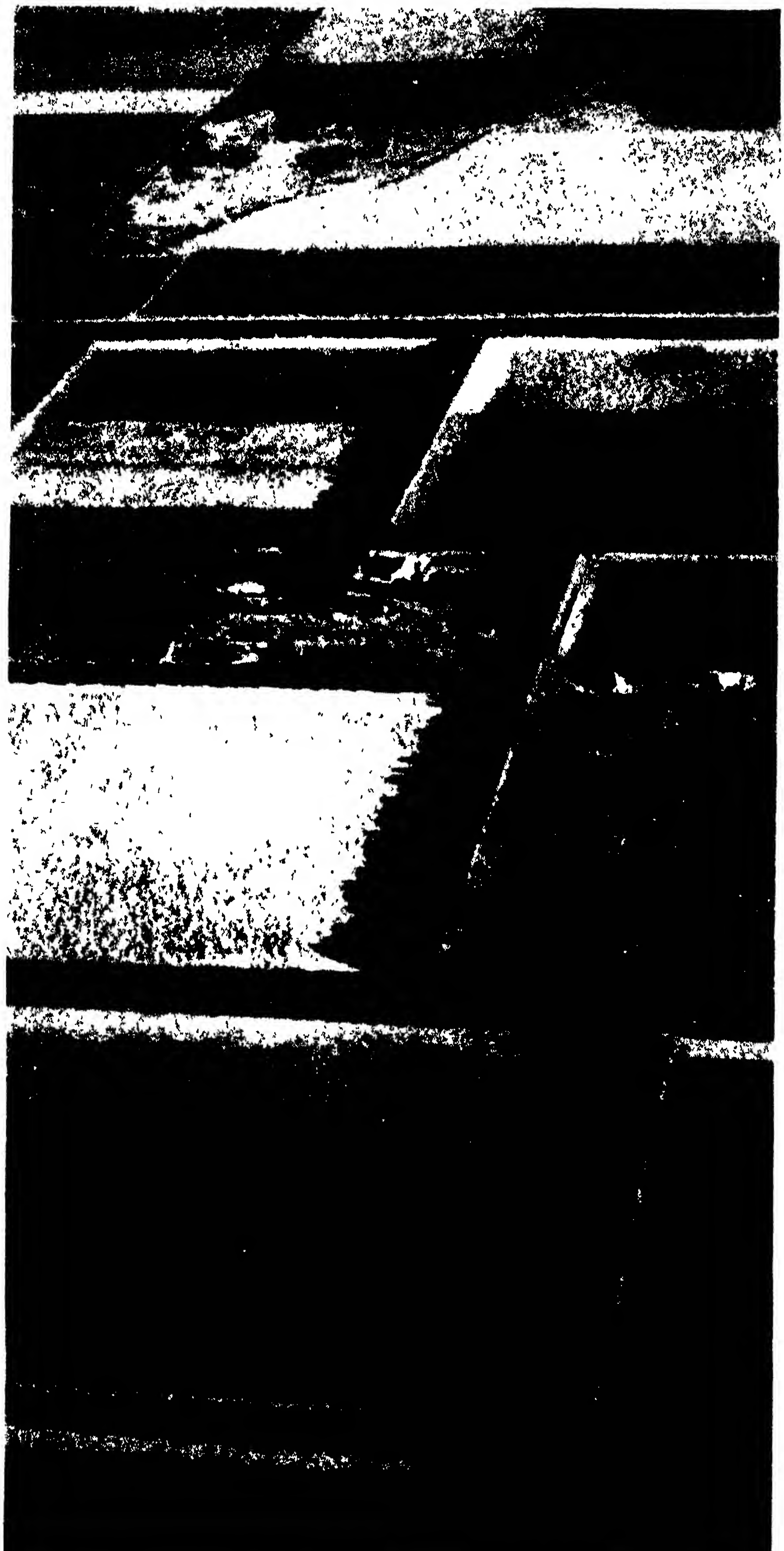
THE DUST STORMS OF 1948

The drifting soil of marginal lands in New Mexico and west Texas is an ominous reminder of the 1930s

by H. H. Finnell

ON THE GRAY prairies of the Southwest, the dust is blowing again. Over wide stretches of New Mexico and west Texas the ominous signs are plainly written. Drifts of soil lie banked across the roads, and yellow clouds have begun to rise from the naked land. The specter of a new dust bowl haunts the Great Plains. It has developed rapidly, but not unexpectedly, within the past few months. Three years ago the black cycle of wind erosion that began in the 1930s was finally ended; in the whole plains country that year there was only one major dust storm. Last year three big dust storms sprang up in the cotton, sorghum and bean area of Texas and New Mexico. This year, in the blow season from January to May, there were 17. Of the 3.5 million acres of farming land darkened by the storms, more than a fifth was heavily damaged.

The reason for the new menace is as plain as are the signposts of coming trouble. The dust bowl is developing on the arid western plains, west of the land of the Okies. Its cause is not primarily drought, although below-average rainfall (as measured at Amarillo, Tex.) during the past three years may accelerate the disaster. The major cause is the great wartime plow-up of marginal soils. Much of the land that has now begun to blow has been broken out since 1941. Under wartime and postwar pressure for food and fiber, many hundreds of thousands of acres too thin or too sandy to stand up under cultivation have been forced to crop and are still being forced. Texas boosted its wheat crop, for instance, from 32 million bushels in 1940 to 124 million in 1947, and New Mexico from 2 million to over 9 million. While the bloom of the new land was wearing off, the marginal soils performed beautifully. But past experience has shown that farmers have rarely been able to stay on top of such soils very long. After two or three crops the soil begins to break down. This year's outbreak of dust storms



WINDBREAKS OF TREES have been planted on the farm of J. H. MacDougal near the Texas-Oklahoma border. Trees were planted in 1939 under supervision of the Forest Service. Conservation of fields may be estimated by comparison with bleak expanse of unprotected land in background.

along the Texas-New Mexico line was the harvest of the quick decline of stability in the sandy soils.

Will a new cycle of dust be permitted to blow itself out? It need not. We have learned from the dust storms of the past that with scientific controls they can be stopped. It took the lessons of the '30s to drive home the truth that dust storms are less an act of nature than a product of ruthless farming.

The devilish, nagging winds of the Great Plains are said to have made lonely pioneer women in dugouts go crazy. The same relentless, moisture-sucking winds more recently have seemed to make dry-land farming go crazy. Due to the resourcefulness of the plainsmen, agriculture did succeed on the plains, and marvelously—up to a certain point. It is this certain point that most concerns the farmers and ranchers of the wide open spaces, and the conservationists.

During the 1930s the dust storm area in the southern plains that was called the Dust Bowl grew to the size of a big midwestern state. It swelled and shrank and bobbed around on the map for a decade. Farmers groped through the dust for an explanation of the unprecedented scourge. The things that were blamed for it ranged all the way from plows to drought, from people to sun spots, from gas wells to sin. The suggested remedies were of an equally fantastic variety. They included such ideas as coating the soil surface with plaster of Paris, junking all one-way disk plows, depopulating the plains, damming a pond on every farm, mulching the land with crushed limestone, planting mulberry trees, irrigating all the cultivated land from wells!

The disaster mounted. There were 40 dust storms in 1935; 68 in 1936; 72 in 1937. The storms were fearful to behold. They gave casual observers the impression that the whole face of the earth was blowing away. Yet this was and still remains a popular misconception. Surveys by the Soil Conservation Service proved that those frightful black blizzards were built up out of dust arising from less than a twentieth of the total Dust Bowl area, and, more astonishing still, from only a seventh of the plowed acreage.

THE ANSWER to the blizzards of dust was eventually found in that vast acreage of farmed land that stayed put in spite of the winds. It was not strong winds alone that caused the storms, for even high velocity winds in the open plains cannot raise dust without soil exposure. Nor was it plowing alone. Experiment and field experience demonstrated that land could be kept safely in cultivation even in the high-hazard areas of wind erosion—provided only that a cover of vegetation was maintained continuously on the soil. The ideal way is to use the residues of productive crops, leaving a stubble mulch

of stalks and straw to tide over the soil from one crop to another. It is surprising to observe how small a quantity of the right kind of litter it takes to protect the soil against a 60-mile-per-hour wind. And the straw from one good wheat crop will hold the soil through the blow season for two years, if it is well managed.

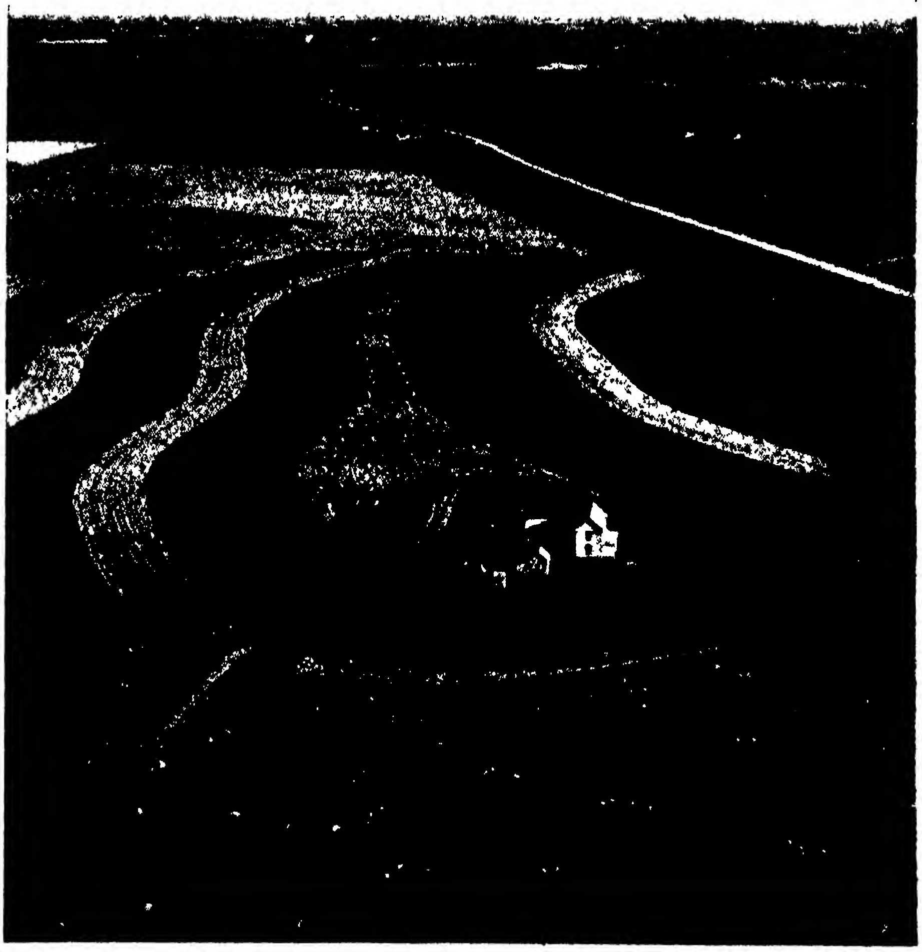
Few farmers on the southern plains had fully realized what a revolution in their soil management problems had been wrought by the advent of winter wheat. In the early days when corn, millet, oats, barley and sorghum were the only crops, wintering the land with stubble standing was the natural and easy thing to do. During the 1920s, when wheat-farming swept over the plains like a prairie fire, three new conditions were injected: 1) soil preparation for this new crop came at the end of the wet season instead of at the beginning; 2) wheat lent itself well to large-scale mechanized production and prompted a huge increase in cultivated acreage; 3) this in turn induced the plowing of considerable areas of low-grade soils. All this, combined with the lack of a stubble residue and with successive years of drought, set the stage for catastrophe. At their height the dust storms became not a local but a national calamity. Frantic emergency aid programs were undertaken to beat down the dust. Progressive farmers, state institutions and federal agencies began a long, slow fight to cover the soil.

THE stubble mulch, called "trashy" farming, proved to be the most universally practical method. The semi-arid climate of the southern plains is favorable to slow rotting of crop residues, and fields were stabilized by successive additions of trash in all stages of decay mixed into the topsoil. Farmers were persuaded to grow crops affording a good supply of durable stalks or straw as cover. Contour tillage was introduced to save water runoff, increase yields and overcome crop failures. Curved rows and stubble-mulched fields had never been considered entirely respectable before. They needed any encouragement that science could give. So tests were made of crop yields, and new implements were devised to till the soil in such ways as to leave the straw and stubble of crops on the surface for protection.

Although rainfall remained below average through 1940, the tide was turned against the dust in 1938. That year there were 61 major dust storms, 11 fewer than the year before; in 1939 they fell to 30; in 1940 to 17; and by 1945, with increased rains, the cycle dropped to the low point of a single dust-bearing storm.

In the end, a recapitulation of the damage to our soil resources told an eloquent story. All in all, 6,541,000 acres in the southern plains had been put out of cultivation by wind erosion. But 25,500,000 acres of good soils came through un-

RECLAMATION of Dallam County, Texas, field that has gone into dunes is begun by planting grasses which hold soil and trap dust. This field is classic example of evil of farming poor land. It was put into cultivation in 1931 and farmed for three years. It went into dunes when it was left idle.



MODEL FARM in Grayson County, Texas, uses several methods to conserve water and prevent erosion. Fields are terraced and cultivated along the contours of the land. Different crops are also planted in long strips. Smaller field near the farmhouse is to provide vegetables for the home.

scathed. Of the top-grade wheat lands, only four fifths of one per cent was lost. On medium-grade soils, the loss was 26.5 per cent. Far and away the greatest damage was to the 3,890,000 acres of low-quality soils which had been in cultivation (and were just about played out anyway when the storms and low prices struck in twin fury). Of this poor land, 90 per cent was damaged beyond repair; it could never be restored for cultivation, and even as grazing land its capacity was permanently lowered.

Thus 59 per cent of the storm dust of the 1930s came from poor land, the kind which cannot long be maintained under cultivation. The moral is clear: we could avoid more than half of our dust trouble before it starts by recognizing the limitations of soils and refraining from over-cultivation of poor land.

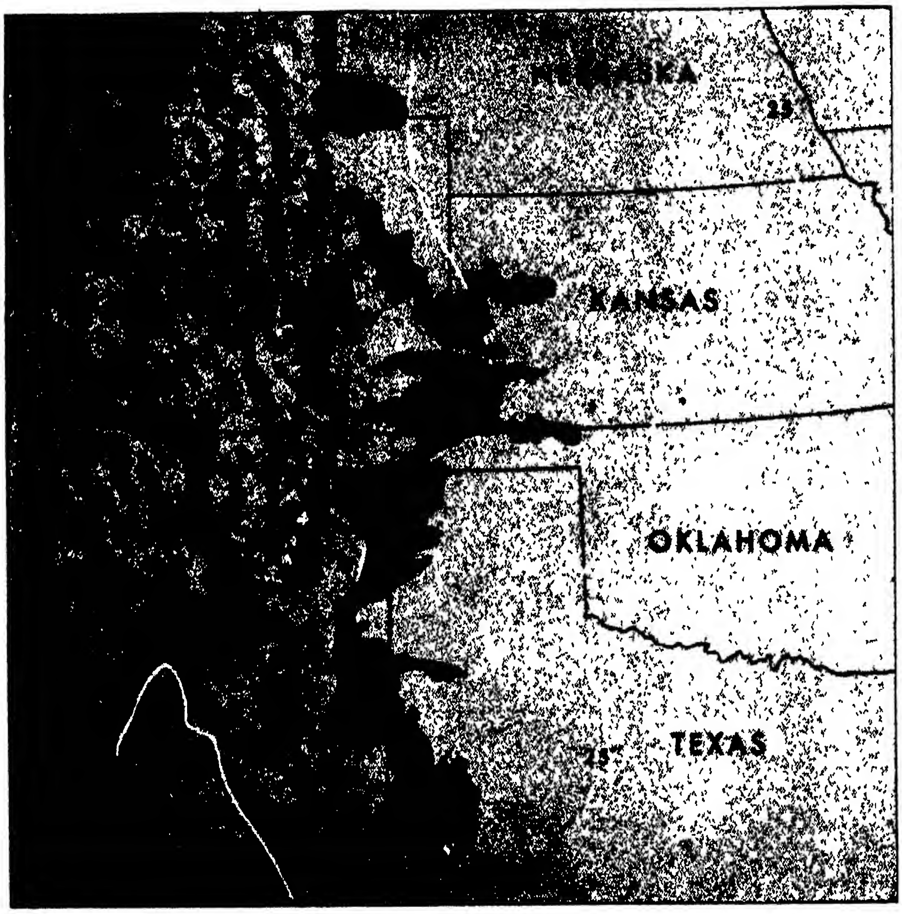
But the problem is not simple. The fact that farmers broke into inferior soils is a symptom of national and world-wide poverty of land resources. It means that good virgin soils have become very hard to find. And the desperate nature of this pinch will become more and more clearly apparent as the years go by. Ironically, the more urgent becomes the need to lighten the pressure on poor soils to prevent their complete destruction, the more difficult the problem will become, for the pressure to use these lands will increase.

The Great Plains, because its acreages and productive potential are vast, is the crucial area to us as a nation. The great weakness of our position in the plains is along the western fringe of dry farming—the area of less than 17 or 18 inches of annual rainfall. This marginal zone of major risk, scene of this year's dust storms, lies beyond the former Dust Bowl areas. The difference is symbolized in the altered color of the dust storms; the black dust of the '30s that arose from the richer loam of Okie territory was less ominous than the yellow storms now rising from the more vulnerable lands of Texas and New Mexico.

This is where semi-arid climate breaks off into arid climate, where the deep soils of the high plains give way to the medium-depth soils and the shallow, where the sandy loams merge into shifty, loose sands. The better lands in this area can be handled safely by stubble-mulch farming, but most of the land should be kept in grass. On the low-capability soils, once taken out of sod, wind-erosion control is a physical impossibility.

It is on this critical soil that the current battle with dust is being fought. Under war's pressure, cotton and feed-crop cultivation in Texas expanded westward, too far beyond that certain point of safety. Farther north, wheat-growing has spread over the shallow clay and silty soils of Colorado, Oklahoma and Kansas—soils that may last a little longer than the sands but that are destined for inevitable breakdown and abandonment. This is the territory of the big land companies and the "suitcase farmer," who leases a tract for a short period, mines it to exhaustion, and moves on.

At the south end of the plains, we are already facing the unpleasant consequences of submarginal cultivation and failure to protect the soil. At the start of the present planting season, 2.8 million acres were not sufficiently protected by cover crops or residues. To date, plantings have failed on about one third of this unprotected area. To head off continued soil-blowing which is in prospect for next year would require a miracle of favorable fall crop conditions. To insure against a long period of trouble we need prompt and drastic action: the immediate converting of the recently plowed poor lands to pasture, which may take several years to accomplish. If events run true to form, however, the operators of these marginal soils will hang on to the bitter end, resisting pleas to save the soil before its final breakdown.

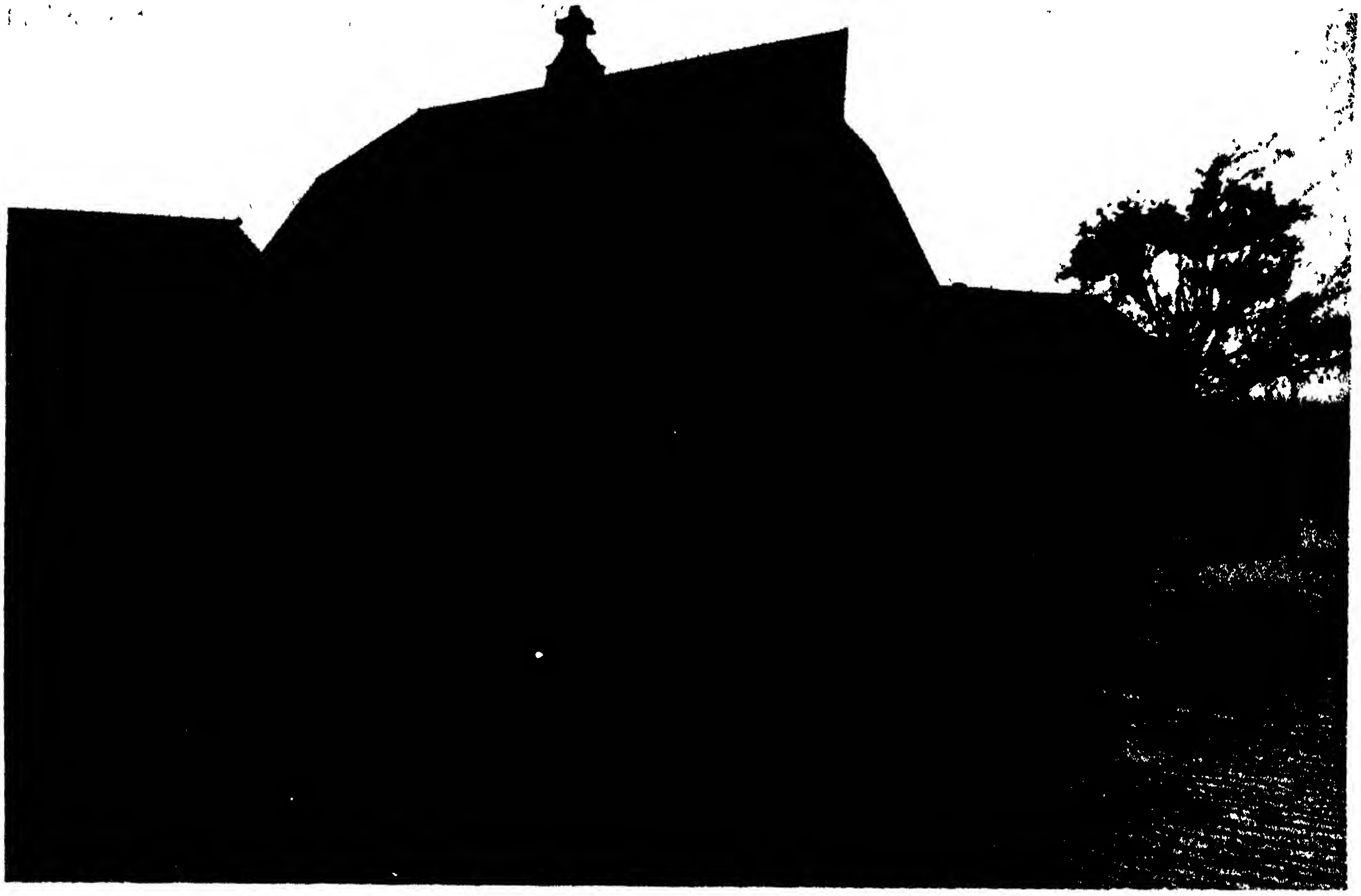


MARGINAL LANDS (*outlined in blue*) **adjoin the established dry farming or irrigated farming areas of seven western states. Three white contour lines indicate inches of average annual rainfall. Farmed during the war, these lands were less able to withstand wind erosion than established areas.**

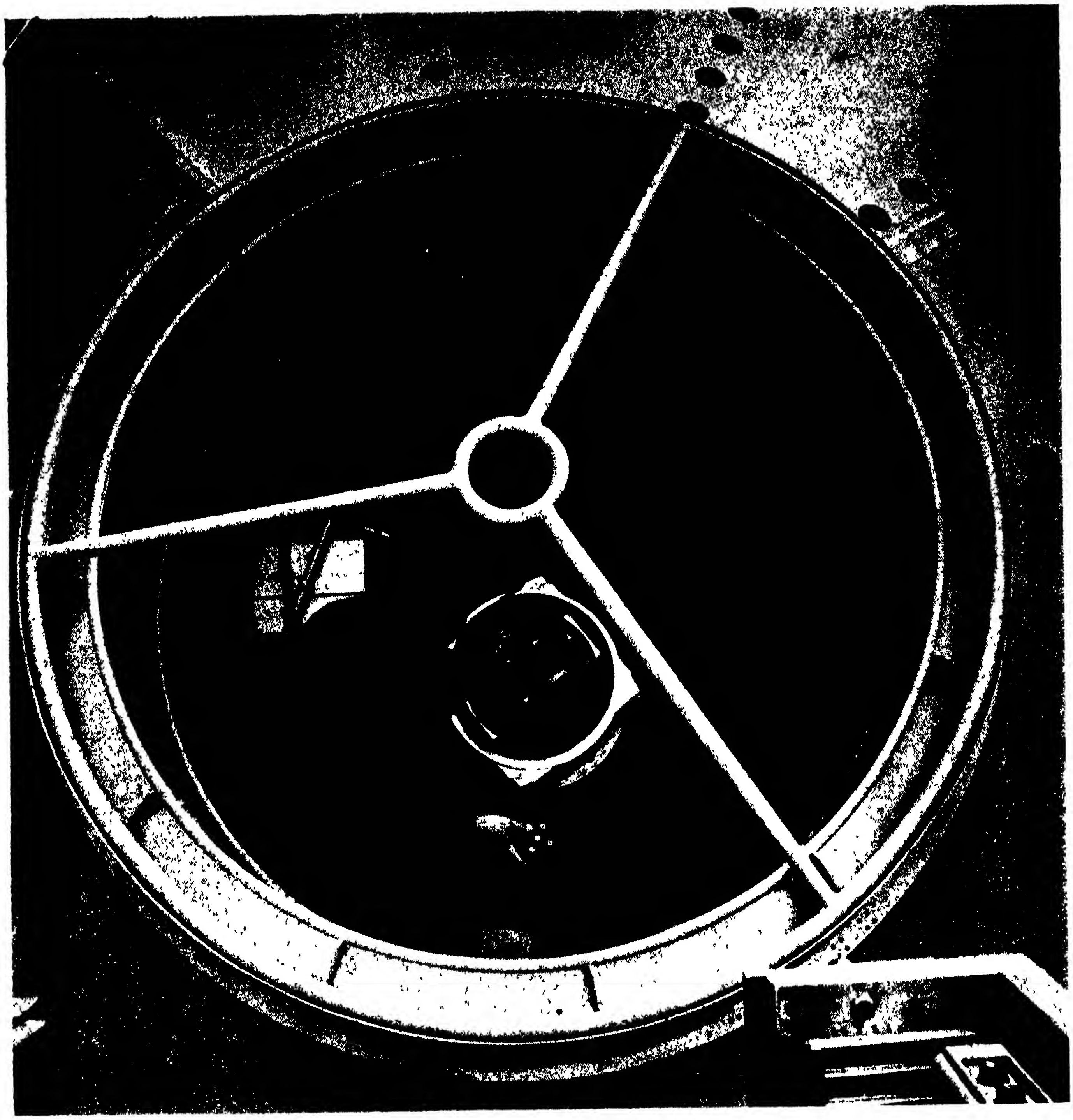
THE PERMANENT residents left behind who will have to contend with the dust, the encroachment of creeping drifts of soil and the long and tedious task of stabilizing blown-out fields, are for the most part members of the Soil Conservation Districts. These districts are legal subdivisions of the states under enabling legislation. Organized and controlled by the member farmers and ranchers, they receive technical assistance from the U.S. Department of Agriculture. Nearly 400 Soil Conservation Districts have been organized in the Great Plains area and new ones are formed from time to time. They have authority to deal with serious erosion emergencies in several ways. One that was widely used in the late 1930s was to accept free leases from distressed or absentee land owners for the purpose of planting cover crops.

But standing by to pick up the pieces is not enough. The land cannot endure one emergency after another. Real and thorough precautions to prevent emergencies from developing are what we need. Maintaining suitable control measures on legitimate crop land is a vital part of that program. Beyond that, we cannot escape the conclusion that it is equally important to keep crops out of arid territory and off the thin and sandy soils of border areas.

H. H. Finnell is research specialist for the Soil Conservation Service of the U.S. Department of Agriculture.

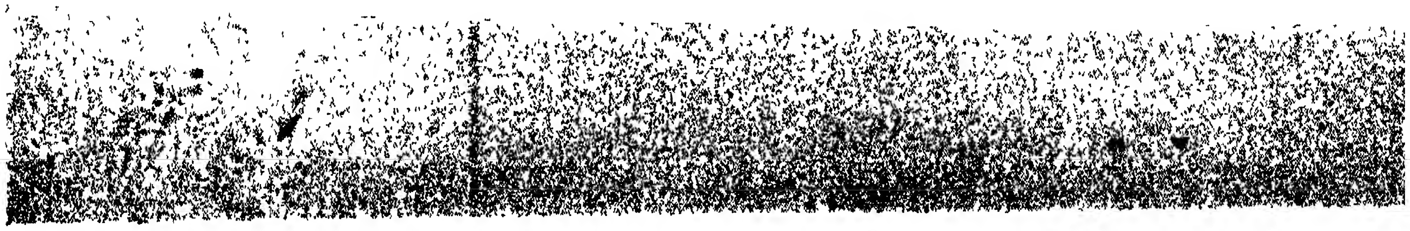


DRIFTS OF SOIL rippled among the buildings of the Karnstrum farm in the 1930s (*above*). Abandoned during the drought and dust storms, the farm was later rehabilitated by planting it with Sudan grass, a tough species which requires little water. In the picture below the surface of the barnyard has been stabilized by a heavy growth of grass. In the fields of the farm, the grass has yielded a crop of 8 to 10 tons to the acre.



PRIME FOCUS of 200-inch telescope *(see diagram on opposite page)* is in a cylinder suspended at upper end of the tube. Here camera looks down toward the mirror. About prime focus cylinder is a plywood screen which is perforated for special mirror tests. The man in the cylinder has his left hand on the prime focus photographic plate-holder. In his right hand are buttons for limited control of the telescope from the prime focus station.

ACTUAL CURVATURE of the mighty 200-inch mirror is less than the common conception but more than any other mirror of comparable size. The 200-inch mirror is *f* 3.3, bringing the light it collects to a focus at a point 3.3 times the mirror's diameter away from its surface. This required that the spherical surface be ground down 3¾ inches at the center. Making the sphere parabolic called for grinding the center .05 inch deeper.



A Night on Palomar

Now that the mirror has been through the early tests, where do we go from here? An account of present problems and future astronomical plans

by Albert G. Ingalls

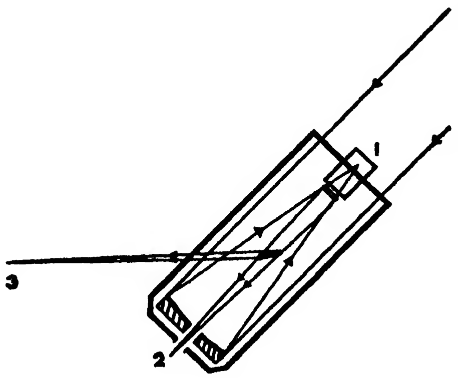
"WOULD YOU be interested," Russell Porter inquired, "in an afternoon, an evening and a morning at Palomar Observatory with the run of the 200-inch telescope and perhaps a squint or two through it, as a guest of the Hundred-to-One-Shot Club?"

The Hundred-to-One-Shot Club is a group of ten middle-aged amateur astronomers, mainly physicists, who during a dozen years have met for camping trips in the desert and mountains. There they relax and have discussions about the philosophy of science, in which the chance of reaching a conclusion runs about a hundred to one.

From Pasadena— where the official owner of the 200-inch telescope, the California Institute of Technology, is located—to Palomar Mountain (not Mount Palomar) is 130 miles by road Thus Palomar is not "just outside Los Angeles." The final 11 miles of the three-hour drive to Palomar includes a seven-mile ascent of the mountain over a fine road that winds in continuous curves up to a broad, rolling plateau. Four miles back on the plateau the silvery silhouette of the 137-foot observatory dome leaps into view. Its observation floor is 5,598 feet above the Pacific.

Arranged around the great dome at thousand-foot distances are the domes of the 18-inch and 48-inch Schmidt cameras. Tucked in a quiet cove under oak trees is the "Monastery," where the astronomers live while actually on the mountain using the telescope. Between times they return to Pasadena to work up their data. The Monastery is an unpretentious modified dwelling run by a steward and stewardess. In it are eight daylight sleeping cells, small soundproof rooms off quiet corridors with special window shutters tight enough to exclude the California sun so the nocturnal astronomer can sleep.

A quarter of a mile from the big dome is the observatory's private picnic ground. Here, while it was still light, we arranged our blankets on the dry ground deep in tall ferns to fend off night breezes. Someone called for an ax and came back dangling a beheaded rattlesnake. Someone else mentioned casually that hundreds of rattlers had been killed there, so theoretically they were "mostly" gone. The anticipation of seeing the 200-inch pushed such thoughts into the background The members of the Hundred-to-One-Shot Club sat down before dark under mistletoe-mottled oaks to eat steaks almost a foot square. Soon it was dim enough to use the telescope.



THREE FOCI of the big mirror give it flexibility for differing problems. They are the prime focus (1), Cassegrainian (2) and the coudé (3).

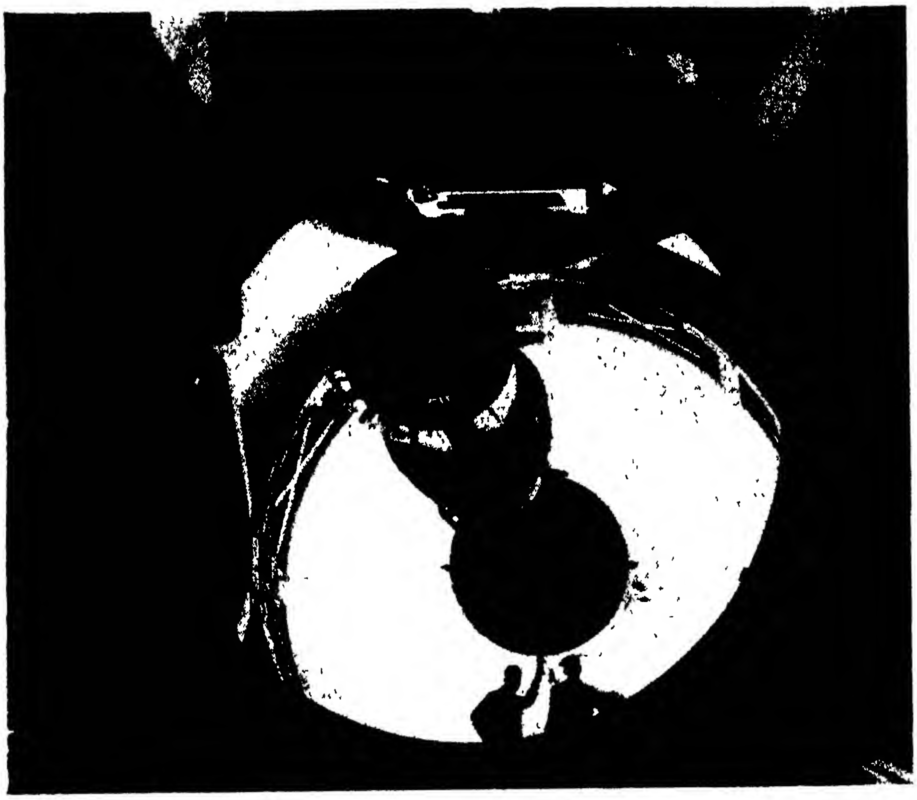
INSIDE the dome of the 200-inch the night assistant perches before a control desk having a satisfying array of dials, indicators and buttons. Here he executes orders given him through a talk box by the astronomers in any of three working positions on the telescope: the prime focus atop the tube, where most of the star photography will be done; the longer Cassegrain focus just under the tube, where the photography of stars or of spectra will sometimes be carried on; and the coudé focus a little below main floor level where stellar spectra will be photographed in a constant-temperature room.

Bruce Rule, engineer in charge of the telescope's vast complex of electrical equipment, much of which he designed, ran the control board. The million-pound mounting obeys the command of a finger. If you wish to point the tube at a given star you look up its declination (celestial latitude) in the astronomer's Ephemeris, turn a little hand crank to that declination, press an "exec" button and the tube swings north or south within its supporting yoke. Then you wind another little crank to the star's right ascension (celestial longitude), press an "exec" button and a three-horsepower "slewing" motor swings the yoke and tube across the skies at 45 degrees a minute A one-twelfth horsepower driving motor then takes hold and keeps the star in the field as the earth turns The actual power needed is theoretically only 1/165,000 horsepower.

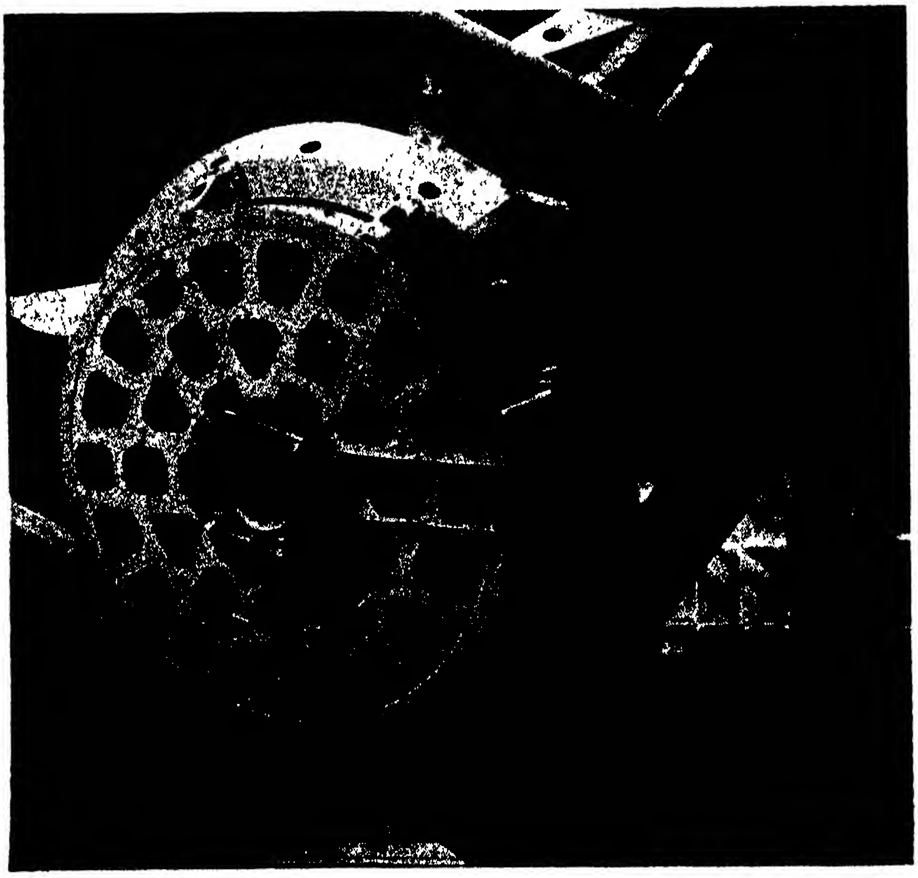
Officially, there is no way to use the 200-inch telescope as a visual instrument. It is a huge camera. However, a crude eyepiece in the form of an eight-power hand telescope had been attached temporarily near the coudé focus at the observatory floor level. This, in combination with the 200-inch, gave a magnification of 800 diameters

With a prolonged carpet-sweeper whine from the slewing motor and worm gears, Rule swung the tube down nearly to horizontal and brought the image of the planet Saturn into the eyepiece. Alas, Saturn was so indistinct that not even Cassini's division between two of the rings could be seen. Otherwise the image was large (one inch apparent diameter) and was brilliantly illuminated by the light collected in the 200-inch mirror. Each person had a look at Saturn, and then Rule swung the tube to Mars. Of all the Martian markings the polar cap alone could be distinguished and that only vaguely.

The members of the Hundred-to-One-Shot Club made little comment about these poor images because they understood the



ALUMINIZED SURFACE of the main mirror, photographed from the upper end of the tube, confuses the anatomy of the telescope. The surface of the mirror is near the flange about the 40-inch tube in the center. Behind the flange are reflections of the tube, the prime focus cage and photographers.



SUPPORTING CELL of the mirror is revealed in a view of the lower end of the telescope tube. Through the perforations in the cell are visible the 36 lever mechanisms *(see opposite page)* that support mirror in all positions. Friction in these supports is a temporarily unsolved problem.

reasons for them. Light from objects too near the horizon passes through many added miles of atmosphere whose varying density causes irregular refraction. In any case, all understood that the visual use of the 200-inch was no more than a stunt. They knew also that a six-inch telescope might at times provide a better show, except for the brilliant images made possible by the big mirror. They knew, too, that they had been privileged to play with the 200-inch only because it was not yet ready for serious work.

Now the telescope was tried on Messier 13, a globular cluster of 50,000 stars 36,000 light-years distant. It easily resolved the cluster. We could look through it and out into the blackness of space beyond. The secret of the suddenly improved seeing was that M 13 was near the zenith and the rays from it had passed through a minimum of atmosphere.

Dr. John Anderson, who with his superintendent Marcus Brown made the mirrors of the 200-inch, exclaimed, "This image is wonderful. It could be photographed." Later at Pasadena he handed me the only six plates thus far made with the telescope and a magnifier for examining their images. They looked excellent. These six plates, however, had been taken only to locate the optical axis of the mirror.

To have supposed that the telescope would be ready to start working as soon as the 200-inch mirror was added to the waiting mounting would have been naive. You can set up a Sears, Roebuck windmill with the wrench in the bottom of the box and use it at once, but a 200-inch telescope is not a windmill and many fine adjustments must be made.

We left the rigged-up eyepiece and wandered for hours among electrical mazes in the rooms beneath the observation floor. Much of the electrical equipment consists of interlocking controls to prevent absent-minded observers from using in damaging sequence the 60 control motors that operate parts of the telescope. We saw the vibrating-string time standards that are accurate within less than a tenth of a second a day, the pumps that force oil at 210 to 385 pounds per square inch under the bearings of the mounting so that the whole million-pound telescope floats on a film of oil. We poked our heads into the kitchen where the astronomer may get a refill after a chill night aloft, and into the lounge where he may study, read or loaf between jobs.

The optical essence of the two-million-pound telescope weighs less than a quarter ounce. Light from the stars reaches a paraboloidally curved aluminum mirror 200 inches in diameter and 1/200,000-inch thick—an amount of metal approximately the bulk of a nickel—which reflects it to a light-sensitized sheet of photographic emulsion a thousandth of an inch thick. The remainder of the telescope consists of accessories: the glass plate that supports the emulsion; the glass disk, commonly

called the mirror, that supports the aluminum; the 36 levers with counterweights that support the glass disk and the platform or cell that supports both; the tube that carries the cell; the yoke that carries the tube; the base frame that carries the yoke and the big steel balls that carry the base frame and rest on plates set in Palomar's gray granite. The function of all these accessories is to support the mirror and emulsion in correct geometrical relation and to move them precisely and controllably.

Of all these mighty bones and vital organs only one, the lever support system beneath the main mirror, still keeps the 200-inch telescope a little under the doctor's care.

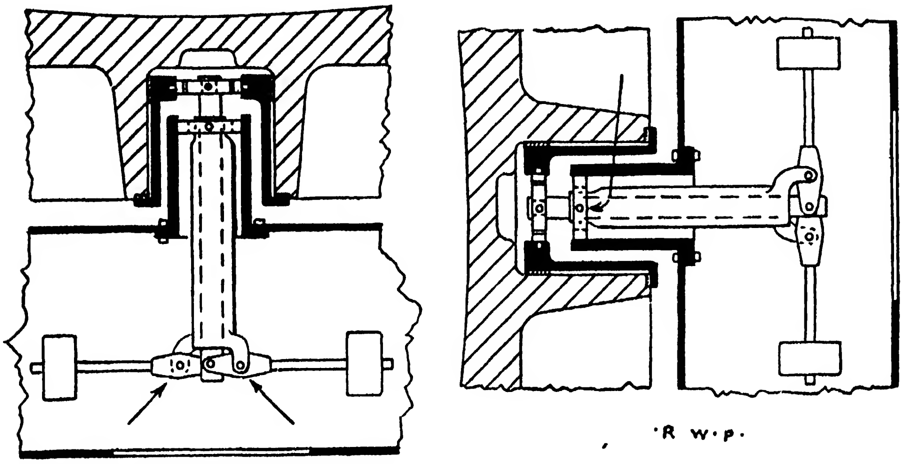
If the mirror disk were made of solid glass two feet thick, two specific effects would be so pronounced as to forbid its use in a telescope as large as 200 inches in diameter. The first is that when the mirror was tipped up at an angle it would slump appreciably of its own weight. The second is that because of changing air temperatures around the disk it would never cease bending. It is true that in a constant-temperature room it would reach one temperature throughout after about two days and thereafter its outer and inner layers would cease to contract and expand unequally. But in a telescope, even within a dome that is insulated against daytime heat by aluminum foil equal in value to 24 inches of cork, the night-time changes of temperature would chase one another continually through its mass. And so poor is glass as a conductor of heat that the optical surface would never cease flexing from the unequal expansion.

To defeat this bogey the Corning Glass Works suggested a cellular disk consisting of a face four inches thick and, cast as part of it, rear ribs four inches thick. In such a disk, no part of the glass would be more than two inches from the air. By this one trick the temperature-equalization time was reduced from the inadmissible 48 hours to a very workable 80 minutes.

The ribbed structure also afforded two other gains: 1) the weight was reduced from 25 to 14½ tons; 2) the ribs permitted the installation of a balancing mechanism At their intersections, 36 deep round pockets were cored out and into these pockets lever mechanisms were inserted to support the mirror over its entire area. These levers balance the weight of each of the 36 local areas surrounding them, and pass the weight to a steel cell beneath the mirror. They are effective in all positions of the mirror between horizontal and vertical because they combine two lever principles. These are worth studying in the accompanying drawings. In both cases shown, horizontal and vertical, the fulcrum is indicated by arrows. In all positions between the two extremes the same lever automatically and at one time acts on both principles in proportion to the tilt of the mirror So fine are these supports that even if the mirror were as thin as paper it would theoretically still be supported in all positions without flexure. Actually—and here comes a headache—the adjustment of the balancing weights each along its lever is an endless game because change of one support effects areas of the disk beyond its allotted territory.

The supports have recently been the optical sore thumb of the telescope. Refined as they are, each with 1,100 parts (the drawing is greatly simplified), there has remained within them residual friction amounting to about 1.3 per cent of the weight supported. This caused enough lag in response as the mirror took new angles of tilt to prevent it from remaining within the required 1/200,000 inch of a true paraboloid.

Just how important the "trifling" amounts involved can become in a large mirror is heavily underlined in the following data supplied by Anderson. If no local support system were provided under the 60-inch mirror at Mount Wilson—if it were supported only at the edge—the sag in wavelengths of light (each approximately 1/50,000 inch) would be 4; in the 100-inch mirror it would be 12; in the 200-inch mirror it would be 125. The amount of sag that can be tolerated is only one-fourth wavelength. The 200-inch would therefore sag to the extent of 500 times the allowable amount!



SUPPORTING MECHANISM of the mirror is made up of 36 relatively simple arrangements of weights. When the mirror is horizontal *(left)*, each pair of weights pushes upward against its surface. When the mirror is vertical *(right)* the supports operate against ribs on back of the mirror.

Newly designed supports are expected to reduce the friction lag from 1.3 per cent to only 0.05 per cent. If they are successful, and they probably will be, they will be installed and adjusted in September. After their first adjustment the mirror probably will perform satisfactorily at once. If it does not, a long series of adjustments may be necessary. These would not be so simple as adjusting a nut with a monkey wrench. The procedure would be to make trial adjustments and to observe the effect on the mirror. The observation would consist of making a Hartmann test photographically. For each such test a week would waste away.

During this period wild rumors may spread by grapevine. Those responsible for the success of the telescope are entitled to a generous period of time for making their adjustments. Cautious readers should judge rumors with reservation. Three decades ago it took a year and a half to adjust the 100-inch telescope and even then the support system contained a heavy friction lag for the first 10 years, until ball-bearing supports were installed. The supports of the 200-inch are also ball-bearing.

THREE DECADES of technical advances have been utilized to the utmost in the 200-inch. This is most notably true of its many remote-control mechanisms. Push buttons and small motors accomplish what formerly was done more slowly by hand. There are 60 small motors and 68 Selsyn units in the installation. An example of the value of remote controls which permit the telescope to be used to its greatest advantage was given me by Dr. Edwin Hubble.

The astronomer is working at the prime focus at the top of the tube but the air is unsteady and tremulous and he cannot get high resolution. Suddenly it settles down. He wants to get large-scale spectra of the components of a certain double star, so he pushes buttons that start motors that move auxiliary mirrors into place, and descends quickly to the coudé focus to carry on with his program. Elapsed time: 15 minutes.

Again, the astronomer is at work with a photocell at the prime focus. Along come intermittent clouds that destroy his brightness measurements. Leaving his photocell, he puts on the coudé focus and spectrograph—time 15 minutes—and works there. The only effect of passing clouds here is to delay the progress by lengthening the exposure. Later the clouds pass over and he easily changes back to his

brightness measurements at the prime focus.

With the 100-inch at Mount Wilson there has been no such flexibility. The best the astronomer could do was to have two or three different programs at hand and choose the one best suited to the night. But, once started on it, he couldn't well change to another, since the change from prime to Cassegrain or coudé focus took more than an hour. Even then conditions might shift while he was changing over.

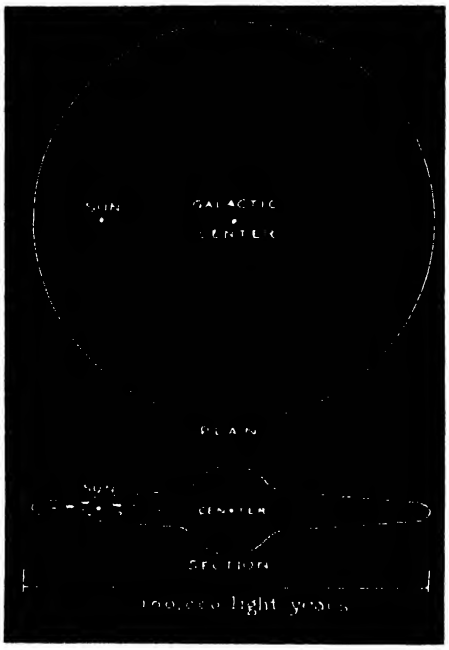
The 200-inch has been named the Hale Telescope in honor of George Ellery Hale (1868-1938) whose vision and leadership made it a reality. Hale, the founder of the Yerkes and Mount Wilson Observatories, obtained $6,550,000 from the Rockefeller Foundation General Education Board for the California Institute of Technology to build the telescope, which Caltech owns. Now that it is built, the astrophysical staffs of Mount Wilson and Caltech have been merged under the direction of Dr. Ira S. Bowen, formerly of Mount Wilson.

At the offices of Mount Wilson Observatory, which are in Pasadena and not on the mountain (10 air, 25 highway miles away), I asked several astronomers to name typical research problems—not necessarily their own—to be carried out by the 200-inch.

The problems stated by Dr. Paul W. Merrill, spectroscopist: 1) Astronomical check on the spectroscopic theory of the iron atom. 2) Analysis of stellar atmospheres to determine motions and accelerations in them. 3) Spectroscopic analysis, as detailed as the new telescope can make it, of the atmospheres of variable stars. 4) Study of long-period variable stars that have been too faint at their minima for further work with the 100-inch. The most interesting problems arise, in fact, when these stars are at their minima.

The problems enumerated by Dr. Walter Baade, cosmologist: 1) Use of the 200-inch to double our sampling of individual stars in the local galaxies. The basis upon which we have begun to explore the universe has been the detailed study of the "local group" or cluster of 14 galaxies within a million light-years. In these we have found Cepheid variable stars which make possible the determination of galactic distances. With the 200-inch we may find Cepheids in more distant galaxies. 2) Study of Type II stars in elliptical nebulae of the local group such as the two companions of the Andromeda Nebula. 3) Extension of our photometric (magnitude) scale to the limit of the 200-inch, to stars of magnitude 22.5. The limit with the 100-inch is about magnitude 21. 4) In the Andromeda Nebula, which is so good a model of our own galaxy that it serves as an excellent guide for its investigation, there are globular clusters similar to the 100 to 200 globular clusters in ours. Photographed by the 100-inch these show only as little round patches not resolved into individual stars. The 200-inch should resolve them and prove that their tentative identification as globular clusters is correct.

EDWIN HUBBLE lists these problems: 1) Determining the relative abundance of the chemical elements in different kinds of stars. These data will have direct bearing on the source of stellar energy and the origin of chemical elements. 2) General problems of cosmology—the structure and behavior of the universe as a whole. Is the region of space ob-



STRUCTURE of our galaxy limits the view of the 200-inch, as it does that of any other earth-bound telescope. Solar system's view of outer space is obscured by dark clouds toward edge and center of galaxy.

servable with the 100-inch, the contents of which are found to be quite similar throughout, a fair sample of the universe? The 200-inch, by penetrating twice as far into space as the 100-inch, will multiply our sample by 2^3, or 8. Again, is the universe actually expanding or is the red shift evidence of some new law of nature? 3) Hubble describes the question of the canals of Mars as an opportunity for the 200-inch, since for the first time it may be possible to photograph by snapshot with that great light-gatherer all that the eye can see with a telescope of moderate size.

Many astronomers react as unfavorably to the mention of Mars as they do to the common use of the word "lens" for mirror and "big eye" for the 200-inch mirror (it isn't an eye but a camera). Thoughtful laymen agree with them that cosmology vastly outranks nearby Mars in significance. But even thoughtful people sometimes take interest in what the next-door neighbors are doing.

Hubble divides Martian observers into two categories: those who claim to see the hairlike canals (adjacent to major markings that have been photographed) and those who don't. If you have seen them, as I have, you will swear they are as real as your hand, but one can feel the same way about optical illusions.

If, however, we could photograph the Martian canals, the dispute would be settled. Mars isn't bright enough for a snapshot with the 100-inch and during the necessary time exposure (a second or so) the fine detail of the supposed canals is smeared over the plate by our atmosphere's evil behavior. (The eye, however, can hold an image, as after a flash of lightning. This is largely how we see the canals and explains why, for once, the eye excels the plate.)

The 200-inch collects just enough light to allow snapshots of Mars. These may be made by having movie film ready to run off during a few minutes of "good seeing" afforded by the atmosphere when Mars is closest to the earth. A few lucky exposures may thus result. The canals of Mars almost never look like the neat maps published in books, which often embody the integrated momentary visions of months or years. Mars will be relatively close to the earth in March, 1950, and May, 1952. Astronomers may then find time to expose movie films.

The 200-inch, the astronomers say, is the last big telescope, "absolutely the final limit in size." Not technological but meteorological obstacles are what set this limit. Just as the 100-inch has been squeezed to its limit so the 200-inch will be. Some future type of instrument, possibly using microwaves, may, however, carry out explorations into new realms of space.

Of equal importance with the 200-inch, or even greater importance during the next few years, will be the 48-inch Schmidt camera at Palomar; yet so religiously do we worship magnitude that the 200-inch has stolen the show thus far. The Schmidt, though its bright dome is conspicuous from the entrance porch of the 200-inch, has not yet caught the public eye.

This big Schmidt camera is firmly wedded to the 200-inch. The importance of the Schmidt is due to the fact that it will photograph the whole sky. Has the sky not been photographed? Not as the Schmidt will do it, not so distantly into space and at the same time so thoroughly.

Ordinary telescopes reach great distances, grasp faint detail, but only in tiny areas. They bore deep but narrow shafts into space. The whole visible hemisphere of the heavens contains about 20,000 square degrees. To cover a single square degree would require about 25 photographs with the 200-inch. It would require an impossible half million photographs by the 200-inch to photograph the entire hemisphere.

The impression is widespread that because the 100-inch has been pushed to the limit it has photographed everything in the sky out to 500 million light-years. On the desk of the cosmologist Hubble is

a chart of the heavens, dog-eared and dingy from years of handling, that shows the area photographed by the 100-inch over three decades. The unphotographed areas exceed the photographed areas by more than a hundred to one. What has been done can be considered no more than sample, though it is a sample that has been systematically distributed.

By about next June the 48-inch Schmidt will begin a program of systematically photographing the whole sky on 1,000 pairs of 14-by-14-inch plates, one red-sensitive, one blue-sensitive. Each will picture an area seven degrees square, with the light-gathering power (distance) of a 60-inch telescope of more orthodox design. Each plate will cover 1,225 times the area of good star images covered by a single plate taken at the prime focus of the 200-inch. And each plate will reveal stars only two magnitudes brighter than the dimmest picked up by the 200-inch (20th magnitude as against 22nd or 22.5)

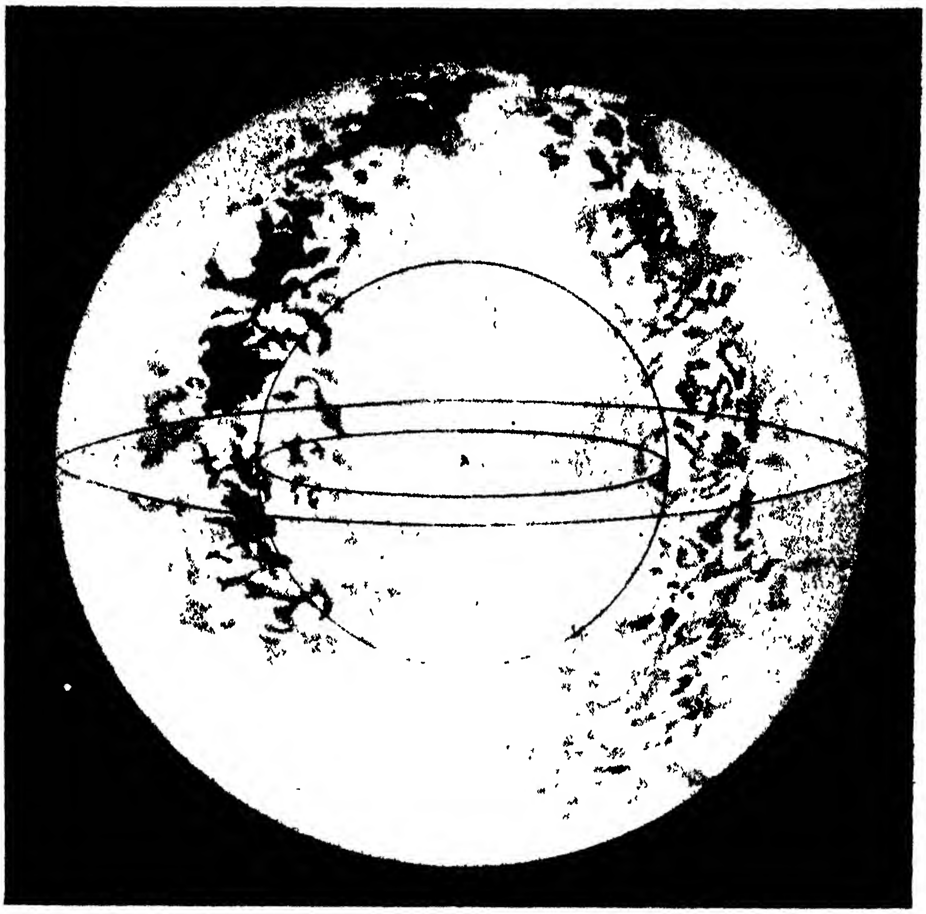
Thus the 48-inch Schmidt will reconnoiter for the deep penetrations of the 200-inch. With it astronomers can seek out likely spots to hunt for significant objects, on which the 200-inch will then be trained. Without the Schmidt the 200-inch, handicapped by its tunnel vision, would be virtually blind.

After a disappointing night without rattlesnake bedfellows, the antivenin provided thus being wasted, the members of the Hundred-to-One-Shot Club washed their faces, omitted to shave, and went to look at the Schmidt. Its optical parts were found in boxes ready for installation.

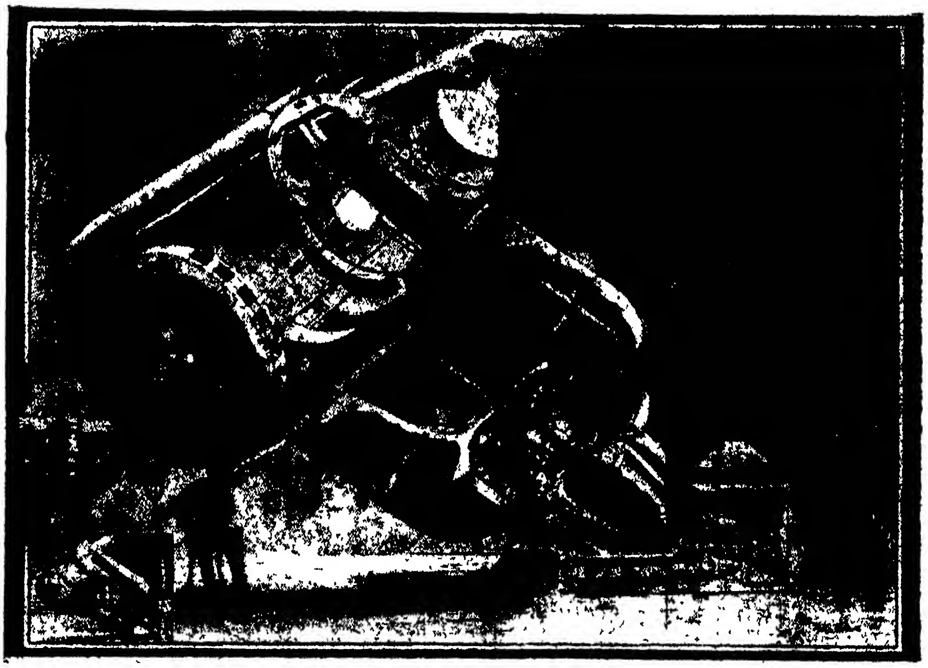
Porter's cutaway drawing shows more of this 20-foot "mortar" than could be seen at the site. The primary mirror, 72 inches in diameter, has a focal ratio of 2.5. The correcting plate has 49-inch clear aperture. The two identical 10-inch guiding telescopes permit control in any position of the tube.

THE 48-INCH Schmidt, like the 200-inch, is a push-button telescope. Dial the coordinates of the desired area, push the buttons and the tube turns to it and stops, ready for work. To insert a plate or remove one, push another button. The camera dutifully nods to horizontal position, facilitating the change. The plate-handling and developing rooms below the observation floor would turn an amateur photographer green.

The Schmidt is off bounds to visitors and so is everything at Palomar except the public parking area, the small museum of Porter drawings and astronomical transparencies, and the glassed-in visitors' gallery on the floor almost beneath the 200-inch. This affords an excellent view. Visitors may here enter freely any day before five and look their fill. With 100,000 of them already arriving annually, the observatory authorities must have some ground rules for visiting if the telescope is to accomplish its work.



VIEW of the 200-inch is a sphere two billion light-years in diameter set in the depths of space. Projected on the surface of the sphere in this drawing by Russell W. Porter are the actual areas obscured by dark clouds within our galaxy. The gap in the lower part of this projection is the area that never rises above the horizon at Palomar Mountain. Within the large sphere is a smaller one representing space penetrated by the 100-inch telescope.



THE BIG SCHMIDT camera will be the handmaiden of the 200-inch in its exploration of space. The precious observing time of the 200-inch cannot be wasted in searching the heavens with its tiny field of view. The wide-field Schmidt, however, can explore freely, revealing areas for the 200-inch to probe. Principle of the Schmidt is that primary mirror at the bottom of the tube is optically corrected by a thin, delicately curved plate at the top.

SWARM OF BEES, going forth to establish a new colony, is covered with a teeming layer of workers. Bees sometimes perform their dance on the surface of a branch, but here communication is less certain than in the hive.

THE

I PROPOSE in this article to describe the amazing experiments of Karl von Frisch on the ways in which bees convey information to their fellows, but first I should like to tell a little about the man himself. Von Frisch is an Austrian who for many years held a zoology professorship at Munich. He was in danger of being thrown out by the Nazis, but his work with the bees was considered so important by the food supply ministry that his dismissal was "postponed" until after the war. During the war the zoological laboratory where von Frisch worked was severely damaged by bombing and his private house, with the library he had moved there for safety, was completely destroyed. He is now working at the Austrian city of Graz. Most of his investigation of bees is carried on in a small private laboratory at Brunnwinkl in the Austrian Alps.

The studies to be described here were almost all made after the war. Most of them are as yet unpublished; some I know from a manuscript submitted to me before publication and the latest from correspondence between von Frisch and myself.

Von Frisch began his work about 40 years ago by showing that bees are not totally color-blind, as was then believed by many on very inadequate evidence. By means of experiments which he originated, he proved that bees have a very definite color sense and can easily be trained to seek food on the background of a specific color which they distinguish from other colors. They are, however, blind to the red end of the spectrum. From this beginning, von Frisch went on to a lifelong study of the other senses of bees and of many lower animals, especially fishes.

His early experiments showed that bees must possess some means of communication, because when a rich source of food (he used concentrated sugar solution) is found by one bee, the food is soon visited by numerous other bees from the same hive. To find out how they communicated with one another, von Frisch constructed special hives containing only one honeycomb, which could be exposed to view through a glass plate. Watching through the glass, he discovered that bees returning from a rich source of food perform special movements, which he called dancing, on the vertical surface of the honeycomb. Von Frisch early distinguished between two types of dance: the circling dance (*Rundtanz*) and the wagging dance (*Schwänzeltanz*). In the latter a bee runs a certain distance in a straight line, wagging its abdomen very swiftly from side to side, and then makes a turn. Von Frisch concluded from his early experiments that the circling dance meant nectar and the wagging dance pollen, but this turned out

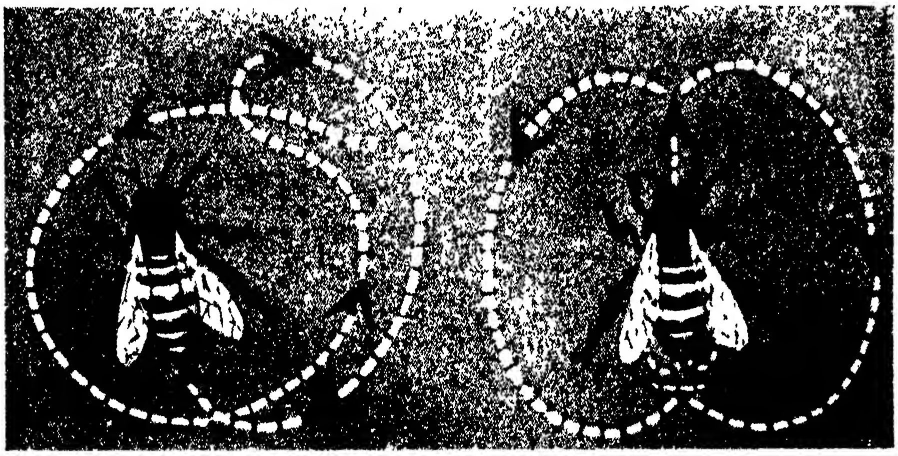
LANGUAGE OF THE BEES

A lone Austrian researcher has deciphered the ritual used by the industrious insect to direct its fellows to pollen and nectar

by August Krogh

to be an erroneous translation, as will presently appear.

In any case, the dance excites the bees. Some of them follow the dancer closely, imitating the movements, and then go out in search of the food indicated. They know what kind of food to seek from the odor of the nectar or pollen, some of which sticks to the body of the bee. By means of some ingenious experiments, von Frisch determined that the odor of the nectar collected by bees, as well as that adhering to their bodies, is important. He designed an arrangement for feeding bees odoriferous nectar so that their body surfaces were kept from contact with it. This kind of



RUNDTANZ AND SCHWANZELTANZ (circling dance and wagging dance) are bee's principal means of communication. In Rundtanz (*left*) bee circles. In Schwanzeltanz (*right*) it moves forward, wagging its abdomen, and turns.

feeding was perfectly adequate to guide the other bees. In another experiment, nectar having the odor of phlox was fed to bees as they sat on cyclamen flowers. When the bees had only a short distance to fly back to the hive, some of their fellows would go for cyclamen, but in a long flight the cyclamen odor usually was lost completely, and the bees were guided only by the phlox odor. The odor gives very precise information about the flowers for which to search. In one experiment in a botanic garden, flowers of the perennial *Helichrysum*, which produces no nectar, were soaked in the sugar solution fed to the bees, and in a very short time their fellows sought out the tiny plot of Helichrysum among 700 species of flowering plants.

THE VIGOR of the dance which guides the bees is determined by the ease with which the nectar is obtained. When the supply of nectar in a certain kind of flower begins to give out, the bees visiting it slow down or stop their dance. The result of this precisely regulated system of communication is that the bees form groups just large enough to keep up with the supply of food furnished by a given kind of flower. Von Frisch proved this by marking with a colored stain a group of bees frequenting a certain feeding place. The group was fed a sugar solution impregnated with a specific odor. When the supply of food at this place gave out, the members of the group sat idle in the hive. At intervals one of them investigated the feeding place, and if a fresh supply was provided, it would fill itself, dance on returning and rouse the group. Continued energetic dancing roused other bees sitting idle and associated them to the group.

But what was the meaning of the circling and wagging dances? Von Frisch eventually conceived the idea that the type of dance did not signify the kind of food, as he had first thought, but had something to do with the distance of the feeding place. This hypothesis led to the following crucial experiment. He trained two groups of bees from the same hive to feed at separate places. One group, marked with a blue stain, was taught to visit a feeding place only a few meters from the hive; the other, marked red, was fed at a distance of 300 meters. To the experimenter's delight, it developed that all the blue bees made circling dances; the red, wagging dances. Then, in a series of steps, von Frisch moved the nearer feeding place farther and farther from the hive. At a distance between 50 and 100 meters away, the blue bees switched from a circling dance to wagging. Conversely, the red bees, when brought gradually closer to the hive, changed from wagging to circling in the 50-to-100-meter interval.

Thus it was clear that the dance at least told the bees whether the distance exceeded a certain value. It appeared unlikely, however, that the information conveyed was actually quite so vague, for bees often feed at distances up to two miles and presumably need more precise guidance. The wagging dance was therefore studied more closely. The rate of wagging is probably significant, but it is too rapid to follow. It was found, however, that the frequency of turns would give a fairly good indication of the distance. When the feeding place was 100 meters away, the bee made about 10 short turns in 15 seconds. To indicate a distance of 3,000 meters, it made only three long ones in the same time. A curve plotted from the average of performances by a number of bees shows that the number of turns varies regularly with the distance, although the correspondence is not very precise in individual cases.

How accurately do the bees respond to what is told them? This general problem can be studied by putting out, at various distances and directions from the hive, plates which are similar to the one carrying food but are charged only with the corresponding odor. An observer watches each plate and notes the number of bees visiting it during a suitable period. Von Frisch found in a typical experiment of this sort that the plates in the same general direction as the feeding place and at a considerable distance were visited by a large number of bees. One placed close to the hive was visited by very few and those in the opposite direction by practically none at all. It was evident that the dance must give information not only about distance, but also about direction. This was made abundantly clear by another experiment. The feeding table was placed in a certain direction and at four different distances in four trials of the experiment. Plates with the same odor were also laid out in the three other directions and in each case at nearly the same distance as

the feeding place. At short distances (about 10 meters) the bees searched almost equally in all directions. But beginning at about 25 meters they evidently had some indication of the right direction, for the plate with food was visited by much larger numbers than the plates at the other points of the compass.

The indication of direction is often several (at least up to 10) degrees wrong, and the uncertainty regarding the distance also is appreciable. The searching bees are helped to find the right place by the odoriferous glands of their successful fellows, who send out into the air at the feeding place the odor which may be specific for each hive. (This odor may also serve as a kind of passport for the bees returning home. All bees having a foreign odor are attacked by the bees on watch at the entrance.)

How did the returning bees indicate to the other bees in the hive the direction of the feeding place? A key to the answer was given by the known fact that bees use the sun for orientation during flight. A bee caught far from the hive and liberated after a few minutes will fly straight back. But if it is kept in a dark box for a period, say an hour, it will go astray, because it continues to fly at the same angle to the sun's direction as when it was caught. Von Frisch deduced that the bee dance must signal direction in relation to the position of the sun. Obviously it is impossible to indicate a horizontal direction on a vertical surface like that of a honeycomb. By watching the dance, von Frisch discovered that the bees make a transposition to a gravity system and adopt the vertical as representing the horizontal direction toward the sun. When the sun, as seen from the beehive, is just above the feeding place, the straight part of the dance is vertical with the head up. When the feeding place is in the opposite direction, the straight part again is vertical, but with the head down. And when the food is not in line with the sun, the bee shows the horizontal angle between the sun and the feeding place by pointing at the same angle from the vertical on the honeycomb.

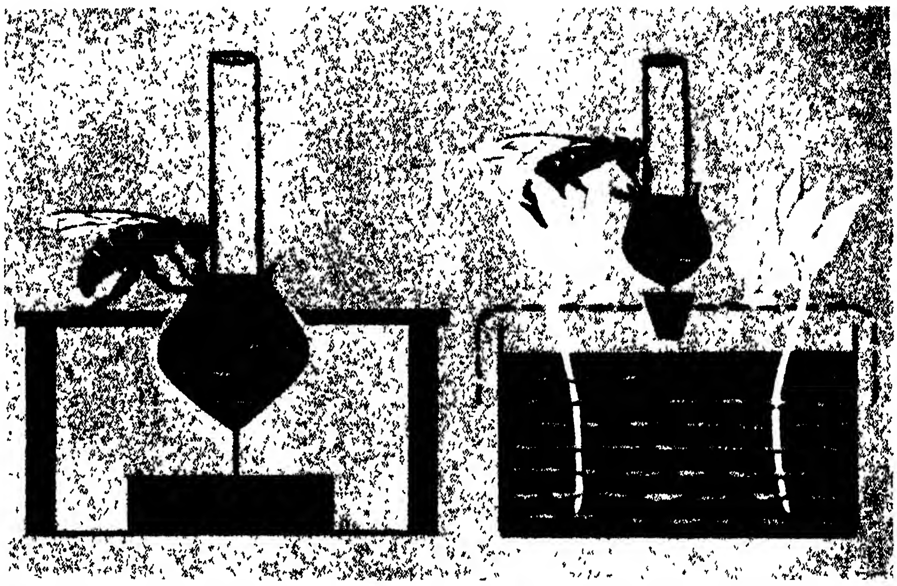
This indication of direction changes continuously throughout the day with the changing position of the sun, which is always represented on the vertical. The dance is normally performed in complete darkness within the hive, yet the bees, roused by, following and imitating the dancer, correctly interpret the signals to an accuracy within a few degrees. It can be observed without disturbing the bees in photographic red light, which is invisible to them.

In the special hive by which von Frisch first made these observations, curious deviations from the right direction were often shown by all the bees simultaneously. Recently von Frisch has found it possible to analyze these and attribute them to perturbations caused by light from the sky.

It is a very curious fact, for which no explanation has been found so far, that the position of the sun in the heavens is correctly used by the bees even when it is hidden behind an unbroken layer of clouds, and when in addition the hive is placed in surroundings totally unknown to the bees. This precaution is necessary because in territory that the bees know well they are experts in using landmarks. It appears possible that infrared rays from the sun, penetrating the clouds, may guide the bees. Experiments have shown that bees are not stimulated by heat rays as such, but the possibility cannot be excluded that the eyes of bees could be sensitive to near infrared although insensitive to visible red. This point has not so far been investigated for lack of a suitable light filter.

VON FRISCH has also undertaken some experiments to determine how the bees would cope with the problem of a mountain ridge or tall building which forced them to make a detour. He found that they would indicate the air-line direction from the hive to the feeding place, but would give the distance that they actually had to fly. One of the experiments of this type is interesting because the bees reacted in an unexpected way. The bees were carefully led by stages around a ridge about three hours' climb from von Frisch's house. The bees, however, soon found that they could save some distance (50 meters) by flying over the ridge instead of around it.

Von Frisch tells me that he himself considered some of these results so fantastic that he had to make sure that ordinary bees which had not been experimentally trained could also do the tricks. They could, and moreover he could see them work on honeycombs removed from the hive. In one such experiment he became curious to see what would happen if the honeycomb was put in a horizontal position instead of the vertical. To his surprise the bees responded by indicating the direction straight to the feeding place, and they kept on doing this even when the honeycomb was slowly rotated like a turntable. It looked as if the bees had a magnet in them and responded like a compass needle, but experiments showed them to be not the least affected by magnetic force. This method of pointing also takes place under natural conditions, the bees often performing horizontal dances in front of the entrance to the hive. It is known that bees in a swarm gathered in a clump on a branch sometimes perform dances on the surface, but it is not known whether this performance is intended to guide them to a suitable new residence.



BEE FED NECTAR without bodily contact (*left*) directs fellows to same scent, proving body surface is not only bearer of odors. Bee fed phlox nectar while sitting on cyclamen flowers (*right*) loses cyclamen odor on long flight.

On the other hand, experiments showed that on the underside of a horizontal surface the bees were unable to indicate any direction, and it turned out that their signals could also be easily disturbed in the shade. Von Frisch therefore decided to test directly their power of indicating direction on a horizontal surface in the dark. A movable chamber was built to enclose the observer and the observation hive. By photographic red light or even by diffuse white light in a tent, the bees proved unable to indicate any direction on a horizontal surface (although they can work with precision in the dark on a vertical one). They continually changed the direction indicated, but they were not restrained from dancing, and the stimulated bees, thoroughly confused, searched for food equally in all directions. The sun can be replaced in these experiments by any artificial light source of sufficient strength. But only if such a light is placed in the right direction, corresponding to that of

the sun at the time, are the bees led toward the feeding place. Placed in any other position, the light will lead them astray.

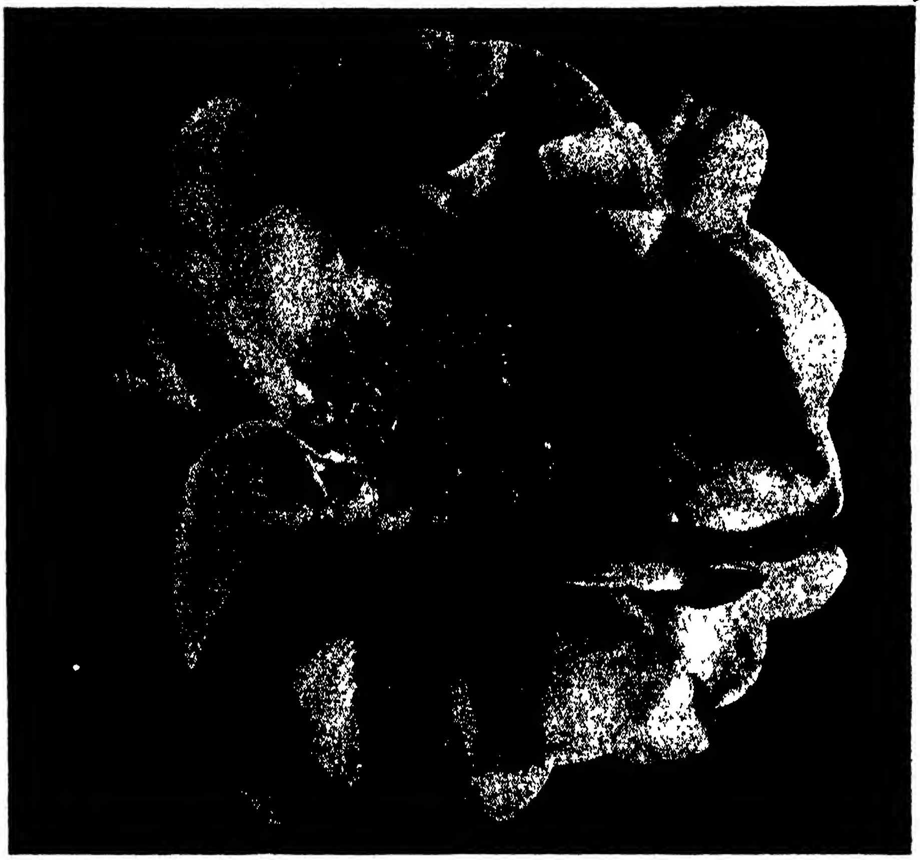
Since the bees had proved able to give a correct indication of direction in several cases when the sun was not directly visible, the experiment was made of removing the north wall of the observation chamber, which allowed the bees to see only the sunless sky. In clear weather this proved sufficient to give them the correct orientation. Indeed, it was eventually found that when light from a blue sky came into the chamber through a tube 40 centimeters long and only 15 centimeters in diameter, this bare glimpse of the sky sufficed to orient the bees toward the sun's position. Light from a cloud, however, was without effect when seen through the tube, and sky light reflected by a mirror was misleading. The most probable explanation is that the bees are able to observe the direction of the polarized light from the sky and thereby infer the sun's position. This hypothesis has not so far been put to the test, as polarizing sheets were not available in Austria.

A SERIES of experiments made on inclined honeycombs showed a combined action of direct light and gravity, the result of which was, of course, a deviation from the true direction. Analysis of earlier experiments, in which light from the sky complicated the gravity reactions of bees on a vertical honeycomb, showed that the perturbations could all be quantitatively explained on the same basis.

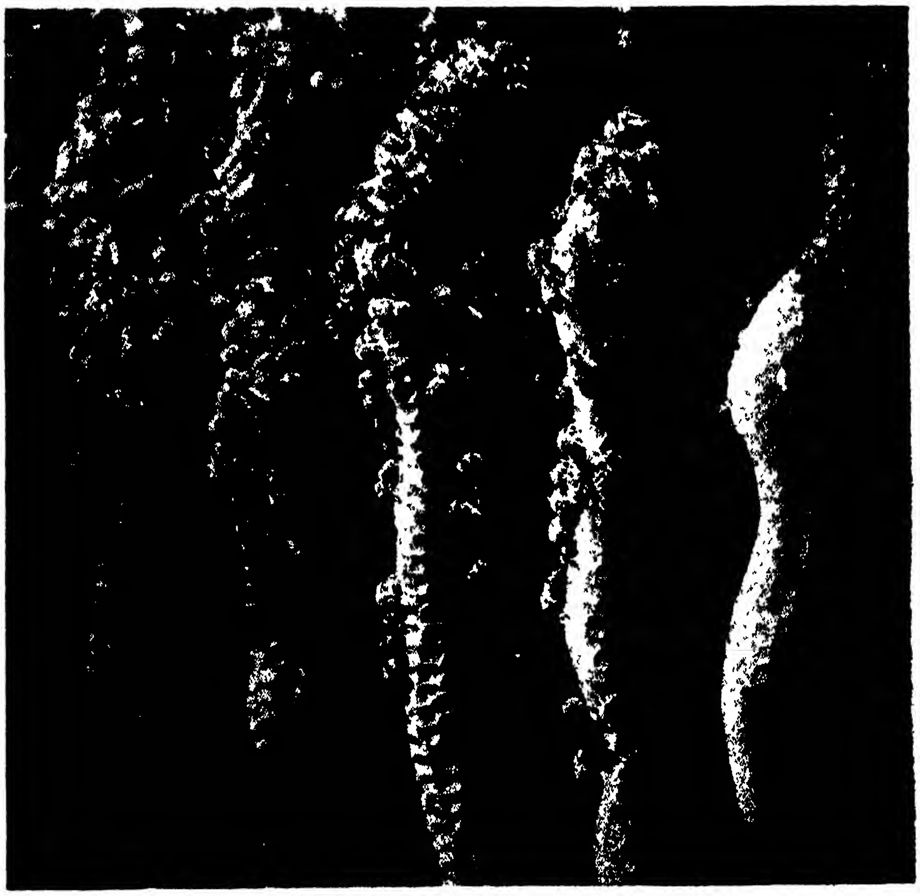
I have tried to give a very condensed account of the principal results which von Frisch has so far obtained. This series of experiments constitutes a most beautiful example of what the human mind can accomplish by tireless effort on a very high level of intelligence. But I would ask you to give some thought also to the mind of the bees. I have no doubt that some will attempt to "explain" the performances of the bees as the result of reflexes and instincts. Such attempts will certainly contribute to our understanding, but for my part I find it difficult to assume that such perfection and flexibility in behavior can be reached without some kind of mental processes going on in the small heads of the bees.

Such processes may be, and probably are, very different from those taking place in the human brain. I would not venture to proclaim them as "thoughts" in the sense in which we use the word, but I do think that something is going on in the brain of the bee as well as in my own which cannot be reduced to the terms of matter and movement.

August Krogh, winner of the Nobel Prize for Physiology and Medicine in 1920, is professor emeritus of zoophysiology at the University of Copenhagen.

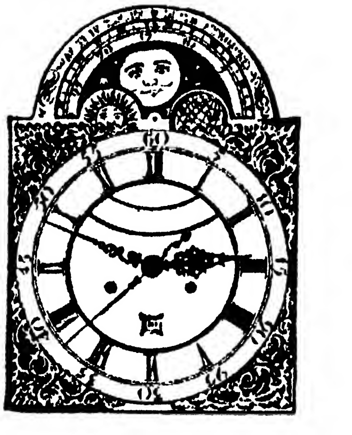


LONE BEE ALIGHTS on a rose to gather pollen and nectar to take back to the hive. Bees sometimes forage as much as two miles away from the hive, yet they are still able to direct other bees accurately to the same flowers.



BEES CLUSTER on the vertical comb surfaces of the hive. It is here that they perform their dance. The movements which convey the direction of pollen and nectar are transposed from the horizontal to a vertical system.

SCIENCE AND



A.A.A.S. Centennial

ON September 13, some 7,000 scientists will gather in Washington for a four-day meeting to observe the centennial of the No. 1 American scientific organization, the American Association for the Advancement of Science. At its first meeting in 1848, officers reported that the A.A.A.S. had 461 members; now it has 50,000 and is growing at the rate of several thousand a year.

The "Triple-A.S." will mark its 100th birthday with an unusual kind of meeting. Ordinarily scientific gatherings are built around the presentation of papers reporting individual researches. As the number of participating scientists and the volume of research have grown, meetings have become more and more unwieldy; the A.A.A.S. assembly in Chicago last Christmas was a grueling marathon of hundreds of papers. For its centennial, the association is inaugurating what it hopes will become a new pattern for scientific meetings. Instead of technical reports, its members will hear outstanding scientists from different fields bring their specialties to bear on common scientific problems in carefully planned symposia and prepared addresses. The 15 symposia and 12 prepared addresses scheduled for its birthday party will, it is hoped, start the A.A.A.S. into its second century with a well-balanced report from key outposts on the endless frontier of science.

Selective Service

SCIENTISTS, advanced science students and doctors are practically exempt from military service under the new peacetime draft law. Although Selective Service headquarters, at the time of going to press, had not yet spelled out how the relevant provisions are to be applied, deferment is clearly indicated for most of the advanced science students and professional researchers who fall within the draft ages (19 to 25). Moreover, a section which would have permitted the drafting of doctors up to the age of 45 was dropped from the bill as it made its final trip through Congress.

In addition to a strong statement in the preamble on the importance of research to the national safety and welfare, the draft law contains this provision: "The President is authorized, under such rules and regulations as he may prescribe, to provide for the deferment from training and service . . . in the armed forces of the United States of any or all categories of persons . . . whose activity in study, research, or medical, scientific, or other endeavor is found to be necessary to the maintenance of the national health, safety, or interest; provided, that no person within any such category shall be deferred except upon the basis of his individual status." In another section, advanced science students are exempt from the provision permitting deferment of college and university students only to the end of the academic year.

When the new Selective Service measure was first introduced into Congress, doctors up to 45 years of age were included at the request of the Army. The Army has been short of medical personnel since demobilization and feared that it would not be able to meet the medical needs of the larger army to be recruited through Selective Service. The rejection of the medical draft will compel the Army to step up its appeal for doctor-volunteers and to recall more of the young doctors who were trained at Army expense during the war and who, in return, were required to accept reserve commissions.

AEC Compromise

AS the result of a last-minute Congressional compromise, the present members of the Atomic Energy Commission will continue in office until June 30, 1950. Early this spring, President Truman nominated AEC Chairman David Lilienthal and his colleagues, whose terms were to expire August 1, to new terms varying in length from one to five years, as specified in the Atomic Energy Act of 1946. The resolutions confirming the appointments were buried by the Senate. Instead, in the last hours before adjournment Congress passed a compromise resolution extending the old terms of the AEC's members for two years. On July 3 President Truman signed the resolution because the present commissioners would otherwise have had only temporary status after August 1 and "because the nation's vital interest in atomic energy requires even the limited continuity of leadership which this measure will allow."

In the case of another amendment to the Atomic Energy Act, the President was successful in registering his objection. During its final weeks, Congress passed and sent to the White House a resolution permitting Senate members of the Joint Congressional Atomic Energy Committee to obtain FBI reports on nominees to the Commission. The President claimed that the resolution was unconstitutional and vetoed it. His veto was sustained.

Owing to a budget cut initiated by the House, the AEC will have some $10 to $20 million less than was anticipated for basic research during the current fiscal year. In his original budget message, the President had asked for $550 million for the Commission, including $90 million for research and development. This was reduced to $512 million by Congress. About $10 to $20 million of the reduction, by Congressional recommendation, is to be taken from research and development, but not from research on weapons, or on biology and medicine. Thus the cut will fall largely on basic research projects.

WHO

THE World Health Organization, which has just wound up a five-week World Health Assembly in Geneva, has provided a rare gesture of Soviet deference to the U.S.

In ratifying the charter of the WHO, Congress made several reservations, one of which—the right to withdraw on a year's notice—raised a question as to American eligibility for WHO membership. Nonetheless, the U.S. was unanimously voted in last month by the Assembly on a motion by the chief Soviet delegate, Dr. N. A. Vinogradov.

Both the U.S. and the U.S.S.R. were elected by the Assembly to the 18-nation WHO executive board. As WHO president, the Assembly unanimously chose Dr. Andrija Stampar of Yugoslavia, rector and professor of public health and social medicine at the University of Zagreb, who had served as head of the Interim Commission that paved the way for the new international health agency.

WHO's permanent headquarters will be in Geneva. Regional offices will be established in five areas particularly in need of international health assistance—the eastern Mediterranean, western Pacific, southeast Asia, and Africa. Latin America will be integrated into the WHO regional organization by affiliation of the Pan American Sanitary Bureau.

Graded Hospitals

IN order to provide modern specialized hospital services to residents of smaller cities and rural areas—one of the most urgent of the world's current medical problems—the hospitals of Sweden 15 years ago were organized into a graded system around metropolitan medical cen-

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ters. The State of Maine four years later instituted a similar plan. The system has been so successful in both Sweden and Maine that it has now been adopted by New York State. This fall New York begins construction of facilities for 54,000 new hospital beds under a five-year, $750 million program to be financed by Federal, state, local and private funds. As they are finished, the new facilities will band together with existing public and private hospitals capable of meeting modern medical standards in seven regional groups. The base of each group will be a score or more of 50-bed community hospitals—at least one within 15 miles of any resident of the state—able to give certain types of care; over the community hospitals will be more completely equipped 100-bed district hospitals; and over them, metropolitan medical centers equipped for the most elaborate diagnostic procedures and care, and also able to serve as teaching hospitals. The plan, which was drawn up by the state's Joint Hospital Survey and Planning Commission, has the backing of every branch of medicine in the state.

Underground Gasification

LATE this fall, the U. S. Bureau of Mines and the Alabama Power Company will conduct another experiment in the underground gasification of coal, a process that holds the alluring promise of producing power from coal without mining it.

Three generations ago, Sir William Siemens suggested that coal need not be mined to produce power. Siemens thought that the combustion processes whereby illuminating gas is made could be carried out underground. Nothing came of Siemens' proposal until the 1930s, when several underground gasification units were built in Russia. Similar experiments have also just been started in England and Belgium.

The first American underground gasification test was conducted last year by the Bureau of Mines and the Alabama Power Company in a small, isolated seam of coal near Gorgas, Ala. The test was generally successful, though the use of too small a seam held down the heating value of the product gas. This year, a larger, deeper seam is to be employed, with the hope of producing a "synthesis gas" suitable for synthetic gasoline manufacture, as well as a heating gas that compares favorably with industrial fuel gas.

Commercial exploitation of underground gasification is still some years away. Effective development of the process, however, might ultimately have a revolutionary effect on the world economy. Besides lowering the cost of synthesis and industrial fuel gases, it might make possible the use of coal deposits too poor to be worked by conventional methods and, most important, free several million men from the hard, dangerous task of digging coal.

Foreign Students

MORE than 20,000 foreign students, a record number, attended U.S. colleges and universities during the 1947-48 academic year. An even larger number is expected to register when the fall semester begins next month.

The rise in foreign attendance at American schools has come about despite the shortage of dollars abroad and despite the fact that only one of the three U.S. Government programs for assisting foreign students is actually in operation. Since 1943, Congress has enacted: 1) a law providing for exchanges with Latin America; 2) the Fulbright Act, under which exchanges are to be financed by the sale of American war surplus abroad; 3) the Smith-Mundt Act, which authorizes exchanges as part of the "Voice of America" program for promoting the U S. abroad. So far, only the Latin American program, which is limited to a few hundred students a year, has made a real start. The Fulbright program has been delayed by the necessity for complex preliminary international negotiations and the Smith-Mundt program by Congress' failure to appropriate funds.

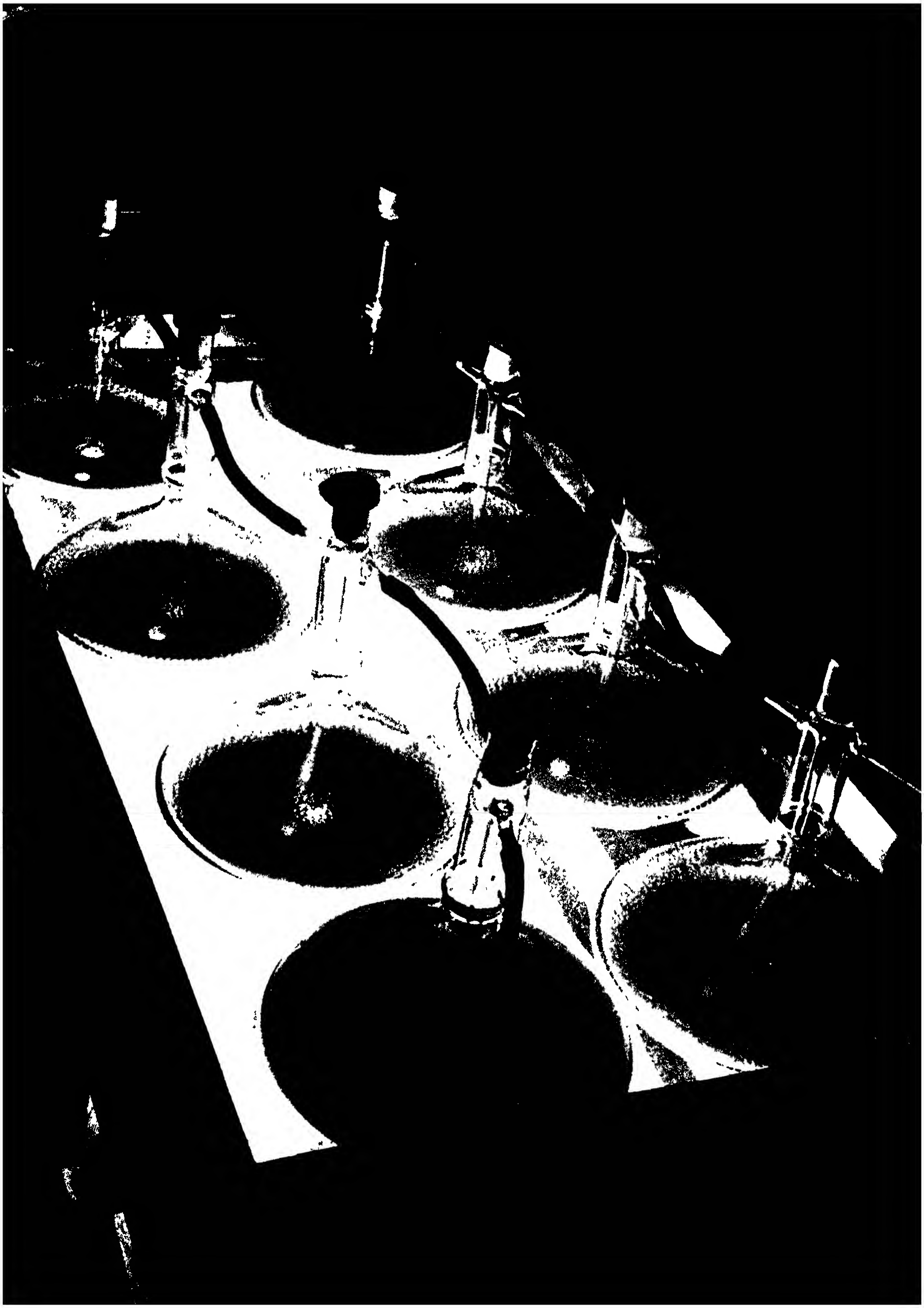
As a result virtually all foreign students now here are being financed with foreign-owned dollars. Since the latter are scarce, their studies represent a genuine sacrifice on the part of their nations—and a tribute to American education, particularly in the sciences and professions, which, it is hardly necessary to point out, are the visitors' main concern. The largest number of students, over 5,000, come from Asia. Latin Americans are in second place.

Meetings in September

AMERICAN Chemical Society, 114th National Meeting. Eastern session, Washington, D.C., August 30-September 3; Midwest session, St. Louis, Mo., September 6-10; Western session, Portland, Ore., September 13-17.

American Institute of Biological Sciences (the new federation embracing the American Society of Zoologists and other biological societies). National meeting, Washington, D.C., September 10-13.

American Association for the Advancement of Science. Centennial meeting (*see above*). Washington, D.C., September 13-17.



PHOTOSYNTHESIS

Life's essential process, performed by stately trees and microscopic algae, is imperfectly understood. But the problem is slowly yielding to a concerted attack

by Eugene I. Rabinowitch

MAN is monarch of the animal kingdom, in aggregate bulk outweighing all other animals except fishes, yet even man is less self-sufficient than the poorest weed in the field. Physiologically speaking, all the animals on land and in the sea, including man, are but a small brood of parasites living off the great body of the plant kingdom. If plants could express themselves, they would probably have the same low opinion of animals as we have of fleas and tapeworms—organisms that must lazily depend on others for survival.

We cannot conceive of life existing on the earth or any other planet without plants; our main reason for suspecting that there is life on Mars is the alleged green coloration of certain parts of that planet. So far as we know, green plants alone are able to produce the stuff of life—proteins, sugars, fats—from stable inorganic materials with no other help but the abundantly flowing light of the sun. This is the process called photosynthesis. Scientists have not been able to imitate it in the laboratory, even on a microscopic scale. But stately green trees and microscopic diatoms alike achieve it every day on a gigantic scale. Each year the plants of the earth combine about 150 billion tons of carbon with 25 billion tons of hydrogen, and set free 400 billion tons of oxygen. Few are aware, incidentally, that perhaps as much as 90 per cent of this giant chemical industry is carried on under the surface of the ocean by microscopic algae. Only 10 per cent of it is conducted on land by our familiar green plants.

A tiny fraction of the organic material synthesized by plants is later utilized as food by animals. A much larger amount is used in the respiration and other life activities of the plants themselves. The greatest part, however, is decomposed into water, carbon dioxide and mineral salts by the decay of leaves and dead plants on land and in the sea. Under certain geologic or climatic conditions the decay is halted. Huge masses of half-decayed plant material then accumulate for millions of years under a protective layer of rock or silt, eventually to become peat or coal.

CHLORELLA, the common green alga, is a favorite study of photosynthesis researchers. Here it is grown in flasks at University of Illinois.

In endlessly repeated cycles the atoms of carbon, oxygen, and hydrogen come from the atmosphere and the hydrosphere (the world sea) into the biosphere (the thin layer of living things on the earth surface and in the upper part of the ocean). After a tour of duty which may last seconds or millions of years in the unstable organic world, they return to the stable equilibrium of inorganic nature.

The organizations of atoms in the biosphere are distinguished from those of the inorganic world by two characteristics: chemical complexity and high energy content. In the inorganic state they are simple molecules of carbon dioxide (CO_2), water (H_2O), carbonic acid (H_2CO_3), carbonate and bicarbonate ions (CO_3^{--} and HCO_3^-). In striking contrast is the complexity of even the simplest organic compounds, such as glucose ($C_6H_{12}O_6$)—not to speak of the enormous and intricate structures which are the molecules of proteins. It is this complexity that permits the almost infinite variability of organic matter. One thing, however, all the multifarious organic molecules have in common: they are all combustible, *i.e.*, they have an affinity for oxygen. When oxidized, they release an average of about 100 kilocalories of heat for each 10 grams of carbon they contain. Thus all organic matter contains a considerable amount of "free" energy, available for conversion into mechanical motion, heat, electricity or light by gradual or sudden combination with oxygen. Such oxidations are the mainspring of life; without them, no heart could beat, no plant could grow upward defying gravity, no amoeba could swim, no sensation could speed along a nerve, no thought could flash in the human brain. Certain lower organisms can exist using sources of chemical energy not involving free oxygen, such as fermentation, but these are "exceptions that prove the rule."

Photosynthesis by plants is the process by which matter is brought up from the simplicity and inertness of the inorganic world to the complexity and reactivity that are the essence of life. The process is not only a marvel of synthetic chemical skill, but also a *tour de force* of power engineering. When plant physiologists and organic chemists study photosynthesis, they are struck most of all by the feat of manufacturing sugar from carbon dioxide and water. When physicists or photochemists contemplate the same phenomenon, they are awed and intrigued by the conversion of stable, chemically inert matter into unstable, energy-rich forms by means of visible light.

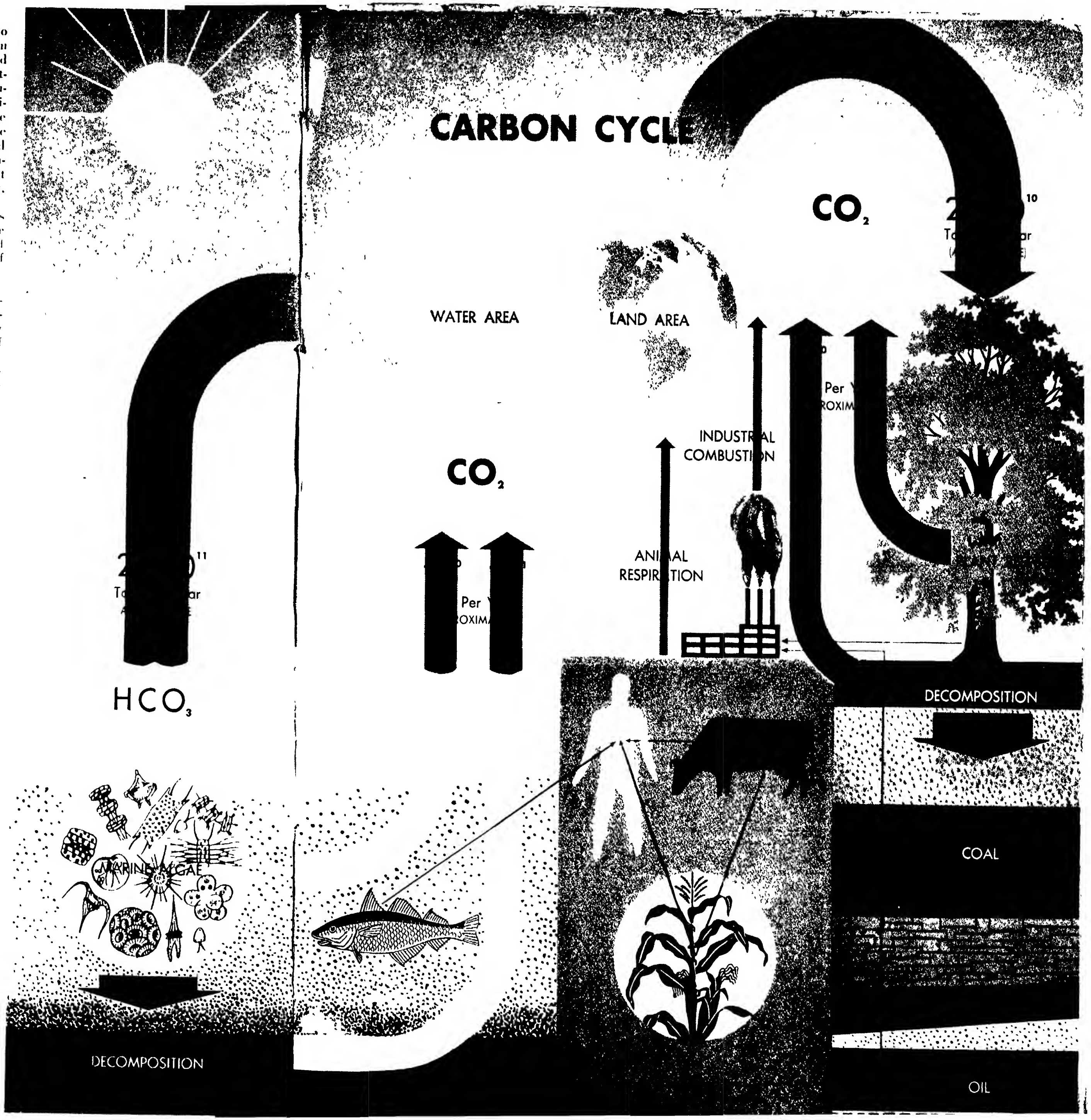
Not only are scientists unable to duplicate photosynthesis outside the living plant cell; they do not know of any halfway efficient method of converting light energy into chemical energy. If we knew the chemical secret of photosynthesis, we could perhaps by-pass plants as food producers and make sugar directly from carbonates and water. If we knew its physical secret, we could perhaps by-pass the "storage-battery" function of plants and produce chemical or electrical energy directly from sunlight. We might decompose water, for example, into an explosive mixture of hydrogen and oxygen that could be used as a source of heat or power.

Historical Beginnings

The story of the little we know about photosynthesis begins with Joseph Priestley, who announced in 1772:

"I have been so happy as by accident to hit upon a method of restoring air which has been injured by the burning of candles and to have discovered at least one of the restoratives which Nature employs for this purpose. It is vegetation. One might have imagined that since common air is necessary to vegetable as well as to animal life, both plants and animals had affected it in the same manner; and I own that I had that expectation when I first put a sprig of mint into a glass jar standing inverted in a vessel of water; but when it had continued growing there for some months, I found that the air would neither extinguish a candle, nor was it at all inconvenient to a mouse which I put into it."

In these words Priestley, religious re-



ENDLESS CYCLE of the element carbon in photosynthesis is really two meshed cycles. Perhaps 90 per cent of all photosynthesis is carried out in the sea by algae, which utilize atmospheric carbon dioxide (CO_2) dissolved in water as carbonate ions (HCO_3^-). Algae return carbon dioxide to the atmosphere by respiration and decay. In respiration, plants reverse photosynthesis, absorbing oxygen and releasing carbon dioxide. All fishes live basically on algae. Some fishes are eaten by man, who returns their carbon to the atmosphere by exhaling carbon dioxide. Land plants take in carbon dioxide and release it largely in decay and respiration. Animals, eating plants and other animals, also return plant carbon to the atmosphere. Industrial combustion releases carbon dioxide by burning coal and oil, which contain plant or animal carbon that has been stored in the earth from geologic past.

former philosopher and spare-time naturalist of the Age of Enlightenment described one of the most momentous observations in the history of experimental biology: the discovery of the capacity of plants to produce free oxygen.

Seven years later Jan Ingen-Housz, Dutch physician to the Austrian Empress Maria Theresa, noticed another aspect of the same phenomenon. Ingen-Housz wrote in 1779:

"I observed that plants not only have a faculty to correct bad air in six or ten days by growing in it, as the experiments of Dr. Priestley indicate, but that they perform this important office in a complete manner in a few hours; that this wonderful operation is by no means owing to the vegetation of the plant, but to the influence of the light of the sun upon the plant. . . . I found that this operation of the plants is more or less brisk in proportion to the clearness of the day and the exposition of the plants; diminishes towards the close of the day and ceases entirely at sunset; that this office is not performed by the whole plant, but only by the leaves and the green stalks. . . ."

Thus was discovered the necessity to photosynthesis of light and of the green pigment chlorophyll. In 1782 a Geneva pastor named Jean Senebier added another important requirement: "fixed air" (carbon dioxide). Only three cubic centimeters of carbon dioxide is present in 10 liters of air, but take this small amount away and all oxygen production in light will stop.

The old and persistent theory of "humus nutrition" of plants (even now many still believe that "good black earth" provides plants with organic nutrients, though in truth it supplies only inorganic minerals) had been shaken a hundred years earlier when the Flemish physician and chemist Jan van Helmont grew a large tree in a bucket of earth. The weight of the earth was not lessened by an ounce. The theory was now ripe for a final overturn. The discoveries of Priestley, Ingen-Housz and Senebier, interpreted in the new chemical language of Antoine Lavoisier, indicated that green plants exposed to light absorbed carbon dioxide and liberated oxygen. An inevitable question arose: what did they do with the other constituent of carbon dioxide—carbon? In 1796 Ingen-Housz supplied the correct answer: the carbon, he said, is the basis of plant nutrition; in other words, photosynthesis is not merely "epuration of air" for the benefit of animals and man but first of all carbon assimilation for the benefit of the plants themselves.

An important ingredient in the chemistry of photosynthesis was still missing; the omission was corrected in 1804 by another citizen of the learned city of Geneva, Nicolas Théodore de Saussure. He found that in addition to carbon dioxide, water also enters into the photosynthetic production of organic matter:

$$\text{Carbon dioxide} + \text{water} \xrightarrow[\text{light}]{\text{green plants}} \text{organic matter} + \text{oxygen}$$

In the absence of light, or in parts of the plant that are not green, the process is reversed: respiration of the plant produces water and carbon dioxide from organic matter and oxygen.

Thus by about 1800 a general chemical definition of photosynthesis was established except for one detail: the recognition that the organic matter manufactured in photosynthesis is a carbohydrate. This class of compounds is made up of carbon combined with hydrogen and oxygen in the same ratio as in water. In the chemist's shorthand carbohydrates may be written $C_m(H_2O)_n$. All sugars, as well as starch and cellulose, are carbohydrates. The conclusion that a compound of this type must be the first product of photosynthesis was reached by plant physiologists in about 1850 on the basis of quantitative determinations of the amounts of carbon dioxide and oxygen exchanged in photosynthesis and of qualitative observations of the formation of starch in illuminated leaves.

It was Julius Robert von Mayer, the German discoverer of the principle of conservation of energy, who first remarked the fundamental physical function of photosynthesis: the conversion of light energy into chemical energy. He wrote in 1845:

"Nature set herself the task to catch in flight the light streaming towards the earth and to store this, the most elusive of all forces, by converting it into an immobile form. To achieve this, she has covered the earth's crust with organisms, which while living take up the sunlight and use its force to add continuously to a sum of chemical difference. . . ."

"These organisms are the plants: the plant world forms a reservoir in which the volatile sun rays are fixed and ingeniously laid down for later use; a providential economic measure, to which the very physical existence of the human race is inexorably bound."

With this perception it became clear that photosynthesis by green plants, in addition to being the only ultimate source of food on earth, also is the only source of animal energy. And indirectly, through the use of wood, coal and peat, photosynthesis is the source of most of our industrial power, heat and light; indeed of all the energy requirements of modern civilization except those met by water power and nuclear disintegrations.

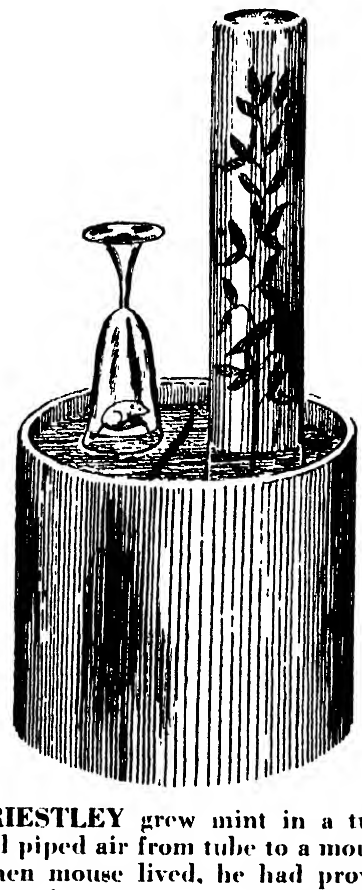
The Challenge Today

Since the discoveries of Priestley, Ingen-Housz, Senebier and Mayer, hundreds of botanists, chemists and physicists have studied photosynthesis. Thousands of papers have been published on its different aspects. And yet we still do not understand photosynthesis as it occurs in the plant—a vexing situation and a continuing challenge.

The biochemist feels that he "understands" a chemical process in the living cell if he knows its successive stages, the intermediate compounds that are formed and the enzymes (biological catalysts) that make the individual stages possible. This knowledge he achieves by taking the biochemical apparatus apart and putting it together again. His ultimate aim is to imitate a biochemical process, such as respiration or conversion of carbohydrates to fats, in the laboratory and to describe each step in detail by chemical equations. Our knowledge of metabolic reactions is rarely so complete, but often we know at least the main stages and can repeat them outside the living cell. We know, for example, the first steps in the breakdown of glucose by animal respiration. They are the formation of a molecule of glucose diphosphate which is then split into two molecules of a triose monophosphate; we know the enzymes involved and can repeat these reactions outside the living cell. It is true that we do not really understand the mechanism by which enzymes produce their characteristic effects, but this is a more advanced problem, the study of which comes after the elucidation of the reaction steps and identification of their enzymes.

In the case of photosynthesis, we know very little about the individual reaction steps and even less about the catalysts which make them possible. We can prepare extracts from plant cells containing chlorophyll or other pigments that are present wherever photosynthesis goes on. But not only are these extracts incapable of photosynthesis (here simply utilizing carbon dioxide and producing oxygen in light), but also we cannot find in them any catalytic or photochemical properties clearly related to the probable steps in photosynthesis. We may then decide that chemical methods of fractionating the plant-cell contents are too drastic, and attempt to take the cell apart mechanically. We take a giant green cell, such as that of some algae, and prick it with a needle in an attempt to reach its interior. Immediately photosynthesis ceases. The cell still respires, it is alive, but oxygen liberation and carbon dioxide absorption have stopped.

Thus we find ourselves in the position of being asked to find out how an automobile motor operates without being permitted to lift the hood. We see that the engine consumes carbon dioxide and water and produces an exhaust gas and chemical energy. We can look at the instrument board and note how the rate of the motor's revolution depends on the supply of fuel, the temperature of the coolant and other external factors, but there is not much hope that we shall ever find out from such circumstantial evidence how the motor is constructed and what chemical reactions take place in the cylinders.



PRIESTLEY grew mint in a tube and piped air from tube to a mouse. When mouse lived, he had proved plants have power to "restore" air.

This was the situation in the study of photosynthesis until quite recently. There was no known possibility of dismantling the biochemical apparatus and studying its parts separately. It was an "all or nothing" situation: at one moment we had a living cell engaged in complete photosynthesis; at the next it was an agglomeration of broken parts or isolated chemical components, with no indications of what role, if any, they had played in photosynthesis while the cell was whole and alive.

Within the last few years the situation has changed. The problem looks less forbidding. Some progress has come from an improved general understanding of the mechanism of chemical, in particular photochemical, reactions. Some has come from the improvement of old experimental methods and the development of new ones: exact analysis by electrochemical and pressure-measuring devices, the use of radioactive tracers, quantitative spectrophotometry. None of these methods, not even the glamorous radioactive tracers, provides an immediate solution to the secrets of photosynthesis, but all of them together promise progress toward the understanding of photosynthesis *in vivo* and its imitation *in vitro*. Beyond these two achievements there beckon grandiose technological goals: synthetic production of organic materials and the unlimited supply of useful energy from sunlight without the help of plants.

Light and Dark Reactions

From measurements of the rate of photosynthesis under different conditions, the English plant physiologist F. F. Blackman concluded as early as 1905 that photosynthesis is not a single photochemical reaction, but must include at least one "dark" reaction (one which is not affected by light). As the intensity of illumination is increased, the rate of photosynthesis (as measured, for example, by the volume of oxygen produced each minute) does not increase indefinitely but approaches a saturation state in which a further increase of light intensity has no effect. This suggests a two-stage process in which only one stage can be accelerated by light. The reasoning may be illustrated by the following analogy. If a million men are to be transported overseas in two stages—first by train to the harbor and then by ship to their destination—the provision of more and faster trains will accelerate the transportation only up to the point where all available ships are used to capacity. Thereafter the further improvement of rail transportation merely jams up the harbor. Conversely, it will serve no useful purpose to provide more ships than can be filled by the arriving trainloads. In photosynthesis there is a stage or stages accelerated by light (corresponding to the railroad journey), and another stage or stages independent of light (the ship voyage). The rate of the latter may depend on how many enzyme molecules—equivalent to ships—are available in the plant cell. It is useless to accelerate the light reaction beyond the capacity of dark reactions to transform the products of the light reaction.

The division of photosynthesis into a photochemical stage and a dark one is

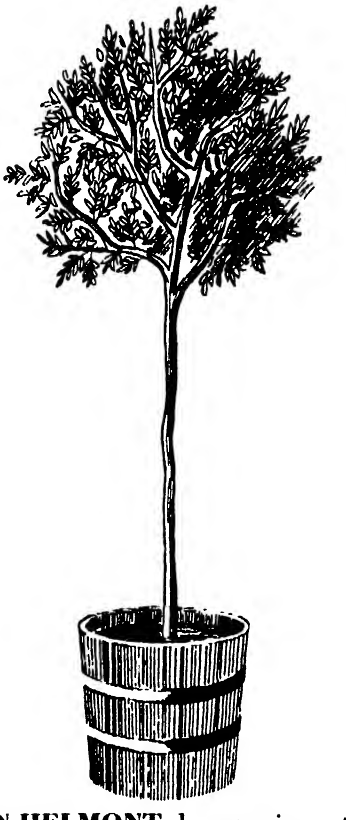
brought out clearly by experiments with flashing light. After a plant is exposed to a brief light flash lasting, say, for .0001 second, the liberation of oxygen continues in the dark for about .02 second; more exactly, a dark interval of about .02 second is necessary to obtain the maximum oxygen production per flash. The experiment measures directly the time required for the completion of the slowest dark reaction in photosynthesis. It is equivalent to the time our ships need to complete the ocean crossing and return to the harbor. It has also been found that there is a limit to the amount of photosynthesis that can be brought about by a single light flash: the maximum yield is about one molecule of oxygen for 2,000 molecules of chlorophyll present in the cell. This is surprising. One would expect that during a short flash each chlorophyll molecule would have a chance to perform its function once, producing one molecule of an intermediate product. Consequently the maximum production would be one molecule of oxygen for each chlorophyll molecule, or for a small number of them. James Franck of the University of Chicago suggested an explanation of the paradox: the maximum yield per flash depends not on the number of chlorophyll molecules but on the number of molecules of the enzyme involved in the second stage (*i.e.*, on the number of ship berths, rather than train berths). In other words, the flash can produce as many intermediate molecules as there are chlorophyll molecules, but comparatively few of them will succeed in completing the subsequent dark stage to produce oxygen.

But why cannot the intermediates wait at the harbor while ships (the catalytic enzymes) ferry some to the other shore and return for a second, third or fourth load? Franck's explanation is that the intermediate photoproducts are unstable. Unless they are immediately processed by a "finishing" catalyst, they disappear by "back reactions" before the catalyst is ready for a second load (as if the soldiers, unwilling to wait, all went AWOL and drifted back to their home towns).

Thus we have the following outline of photosynthesis. It consists of a light stage and a dark stage. The light stage produces unstable intermediates; the dark stage stabilizes them by conversion into the final products, oxygen and carbohydrate. The rate of photosynthesis is limited by the bottleneck of a dark reaction which can process only one molecule, or at most a small number of molecules, of intermediates per 2,000 molecules of chlorophyll each .02 second.

The Use of Light Energy

From our general knowledge of the nature of chemical reactions, particularly those involved in metabolic processes, we can make a guess as to the probable nature of the light stage in photosynthesis. Plant respiration, the reverse of photosynthesis, involves two types of reactions: those which break the carbon chains in the large organic molecules, and those which remove hydrogen atoms from association with carbon and, with the catalytic help of enzymes, transfer them to oxygen, thus forming water. In photosynthesis the same two types of processes must be involved, but running in the opposite direction—the transfer of hydrogen from water to carbon dioxide, and the building of carbon chains. Of these two types of reactions, the transfer of hydrogen is the one that *liberates* energy in respiration, hence this must be the one that *stores* energy in photosynthesis. The energy that is stored comes from light. Consequently the light reaction in photosynthesis in all



VAN HELMONT, by growing a tree in a bucket, showed that plants take little of their substance from earth. Weight of the earth was unchanged.

probability is a hydrogen transfer from oxygen to carbon "against the gradient of chemical potential," meaning from a more stable to a less stable form. To use a mechanical picture, in respiration the hydrogen atoms run downhill; in photosynthesis, the impact of light quanta (discrete "atoms" of light), absorbed by chlorophyll, sends them uphill.

Let us illustrate this reversible process by mixing a solution of the dyestuff thionine with a solution of ferrous sulfate. In intense light, the color of the dye disappears in a second or less; in the dark, the color immediately returns. This is an example of how an oxidation-reduction reaction can run in one direction in the dark and in the opposite direction in light. In light, ferrous iron reduces the dye to a colorless form and is itself oxidized to ferric iron; in the dark, ferric iron oxidizes the dye back to the colored form and is reduced to ferrous iron. A reaction of this type must be involved as the primary light reaction in photosynthesis, the fundamental difference being that the plant is provided with an enzymatic mechanism which efficiently prevents any back reaction in the dark—as long as the unstable light products are not supplied too fast.

The energy content of the final products of photosynthesis—sugar and oxygen—is well known; it is represented by the amount of heat produced when sugar is burned to carbon dioxide and water. The energy is 112 kilocalories per gram atom (one gram multiplied by an element's atomic weight) of carbon. This, then, is the minimum energy that has to be supplied by light in photosynthesis. To reduce (hydrogenate) a molecule of carbon dioxide to the "reduction level" of sugar, four hydrogen atoms must be transferred to the molecule:

$$CO_2 + 4H \longrightarrow C(H_2O)_2$$

To move these hydrogen atoms "uphill" from water to carbon dioxide, each of the four atoms must receive a push equivalent to at least one fourth of 112 kilocalories, or 27 kilocalories per gram atom of hydrogen. These pushes must be supplied by light.

Niels Bohr and Albert Einstein showed in 1913 that light is absorbed by atoms or molecules in the form of quanta of definite energy content, which is proportional to the wavelength of the light. Red light, which is strongly absorbed by chlorophyll, has quanta with an energy content such that it provides about 40 kilocalories per gram atom of the absorbing atoms. Obviously one such quantum is not enough to transfer four hydrogen atoms (requiring 112 kilocalories). Could it be done with four quanta—one quantum for each hydrogen atom? Even this would be a marvelous achievement: the plants would have absorbed 160 kilocalories of light energy and stored 112 kilocalories as chemical energy—an efficiency of 70 per cent.

IN 1923 Otto Warburg, the German cell biologist, first attempted to measure the "quantum yield" of photosynthesis—the number of quanta required to reduce one molecule of carbon dioxide. This implied measuring exactly the light energy absorbed and the volume of oxygen produced. In order to obtain the maximum possible yield, it was advisable to work in very weak light to avoid saturation effects. The measurements therefore were very delicate. The results were striking: Warburg found an absorption of four quanta per molecule of oxygen! This corresponded with the minimum value theoretically plausible, and implied an extraordinary efficiency of plants as energy converters.

Warburg's result, however, did not re-

main unchallenged. Other groups of researchers were unable to confirm Warburg's observations. Instead they found yields of about 10 quanta per oxygen molecule; some values were as low as eight, but none was lower. The question is still unsettled; the weight of evidence favors the higher value: eight or more quanta per molecule of oxygen. Even at this value, however, the 35 per cent yield in energy conversion by plants is very respectable—considering that we do not know of any reaction produced by visible light *outside* the plant cell which would convert as much as 10 per cent of absorbed light into chemical energy. If some economical means could be found to capture and convert even 10 per cent of light energy, the discovery conceivably could produce a greater revoluton in our power economy than can be expected at present from the much-publicized discovery of atomic energy.

One plausible picture of how chlorophyll may use eight light quanta to move four hydrogen atoms from water to carbon dioxide is this: A chlorophyll molecule absorbs a quantum and is raised to an "excited," energy-rich state. It is then able to pull a hydrogen atom away from water (or from a product derived from water by a dark, enzymatic reaction). In this reduced form, chlorophyll takes up another light quantum and uses its energy to force the same hydrogen atom on a reluctant "acceptor," such as carbon dioxide or a compound derived from carbon dioxide by a dark reaction. It is as if a workman, suspended halfway on the face of a building, fortified himself with a drink, hauled a construction piece up from the ground, and then, fortified with a second drink, threw this piece up to the roof.

Chlorophyll and Other Pigments

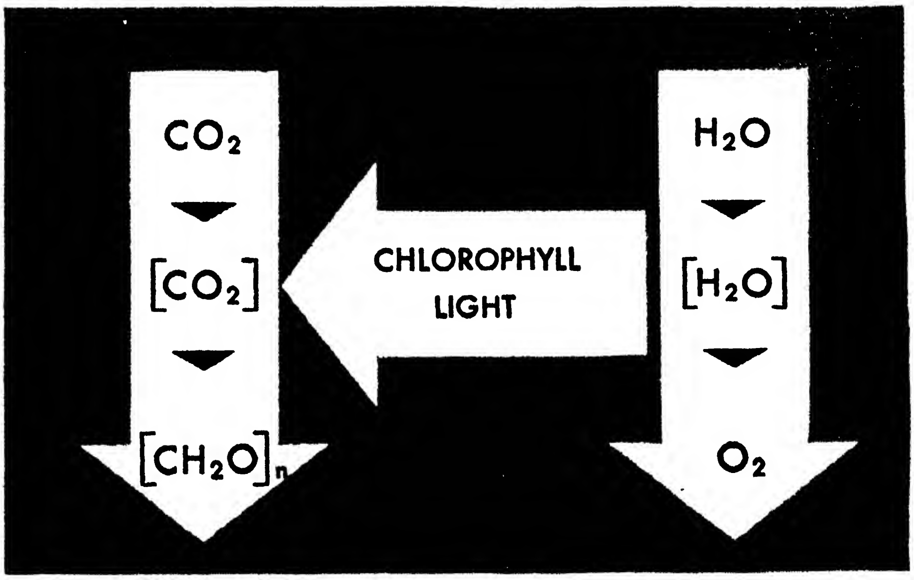
It has long been assumed that chlorophyll is the only agent that can perform this trick. It has been well known that all green plants also contain yellow or orange pigments (carotenoids, identical or similar to the pigments of carrots and egg yolk), and that many algae contain red or purple pigments. But all plants capable of photosynthesis were found to contain chlorophyll, and chlorophyll alone among the plant pigments absorbs red light. Since photosynthesis proceeds satisfactorily in pure red light, light absorption by chlorophyll must be *sufficient* to bring about photosynthesis, and from that experimental fact there is only a short step to the assumption that it is the *necessary* prerequisite.

Recently, however, the position of chlorophyll has been challenged. First, indications were found that the light energy absorbed by the yellow pigments also is utilized in photosynthesis. Then at the meeting of the American Association for the Advancement of Science in Chicago last December, L. R. Blinks of Stanford University presented evidence that in some red algae the light absorbed by red pigments is more effective in photosynthesis than the light absorbed by chlorophyll. If this is confirmed, the red pigments must be assumed to participate in photosynthesis directly, and not merely as handmaidens of chlorophyll. To appreciate the importance of this observation, you must remember it is estimated that 90 per cent of photosynthesis on earth is carried out, not by green land plants, but by the multicolored sea algae.

by its dehydrogenation in light, and then the enzymatic conversion of the residue into free oxygen, perhaps through the intermediate formation of a peroxide, similar to but apparently not identical with hydrogen peroxide.

The Uses of Isotopes

Some of these reactions are now being studied with the help of isotopic tracers. We are concerned with the fate of three kinds of atoms—hydrogen, carbon,



PHOTOSYNTHESIS IS OUTLINED in diagram shaped like the letter H. On vertical leg at right, water gives up hydrogen, releasing oxygen. Hydrogen is then transferred to carbon dioxide by agency of light and chlorophyll. Reduction (hydrogenation) of carbon dioxide produces carbohydrate (*bottom of left leg*). Intermediate steps and compounds (*bracketed*) are unresolved.

So we are beginning to get a somewhat clearer idea of the events in the light stages of photosynthesis, and recently we have also gained a little information about the dark stages. The total process, as we have noted, proceeds in two separate sequences: 1) the oxidation of water, which releases free oxygen, while hydrogen becomes attached to some intermediate "acceptor"; 2) the hydrogenation of carbon dioxide to produce carbohydrates. Each sequence of reactions apparently has a separate catalytic system. The two sequences and their relation to each other are pictured in an accompanying diagram, which shows the separate sequences as two legs, with chlorophyll as the bridge between them. One sequence (the left leg) begins with molecules of gaseous carbon dioxide. These are first bound or fixed in a form suitable for reduction, perhaps by enzymatic formation of an organic acid. The bound carbon dioxide is then reduced by hydrogen atoms supplied in light by chlorophyll, which has recovered the hydrogen from water in the other sequence. The reduction, in turn, is followed by other enzymatic transformations which lead to a carbohydrate molecule.

In the right leg we first have a similar binding of the water molecule, followed

oxygen. The heavy non-radioactive hydrogen, deuterium, (H^2), has been available since before the war; the weakly radioactive tritium (H^3) is not yet generally available. Three isotopes of carbon are usable: the short-lived C^{11}; the long-lived C^{14}; and the stable, non-radioactive C^{13}. C^{14}, which the atomic pile at Oak Ridge has made widely available, is by far the most useful. To our great sorrow no radioactive isotope of oxygen is known; the stable isotope O^{18} offers the only means of studying the fate of this important element. Tracer carbon is an appropriate tool to study the reduction of carbon dioxide to carbohydrate. Tracer oxygen could be equally useful for the study of the oxidation of water to oxygen. Tracer hydrogen could help to trace the processes in the bridge between these sequences, including the primary photochemical process.

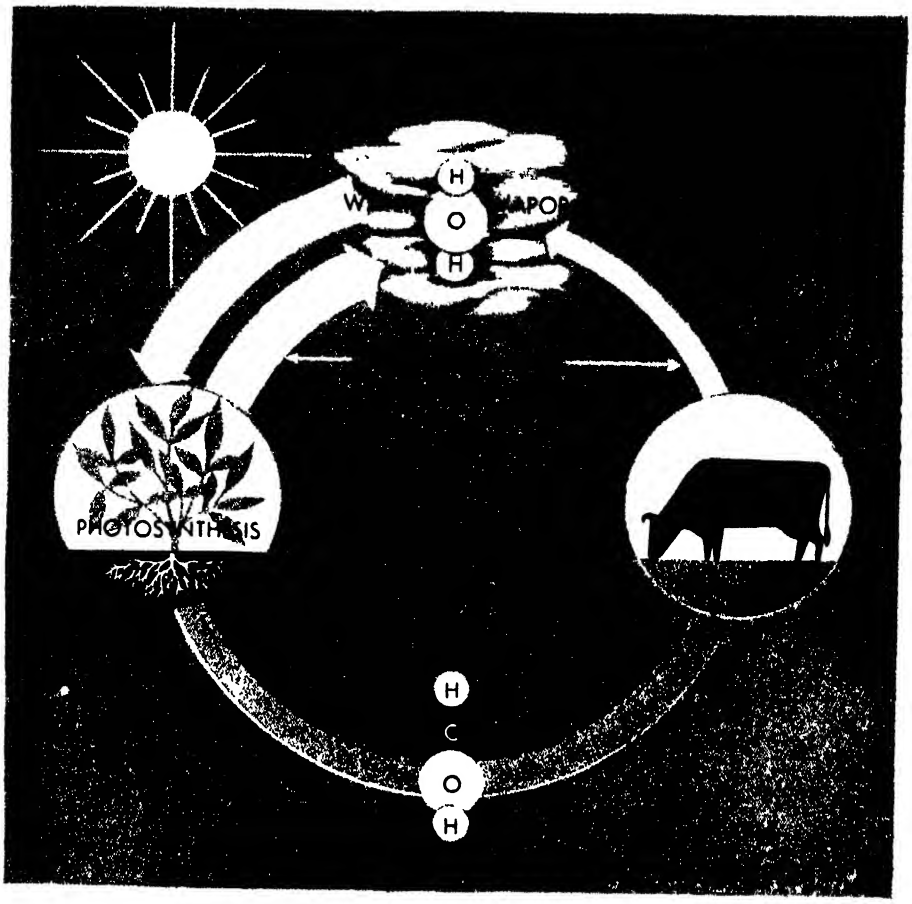
Let us consider first the reduction of carbon dioxide. The process consists of a preparatory dark fixation stage, then a direct or indirect photochemical reduction, and finally the finishing enzymatic transformation, possibly taking place in a series of steps. The two phases where radioactive carbon might be used are obvious: it can be applied in the dark, with the intention of identifying the product

of preliminary dark fixation, or in light, with the intention of identifying the intermediate products formed in light. Depending on the duration of exposure to light, we can expect to find the radioactive carbon distributed variously among the different intermediates and the final products of photosynthesis—sugar, starch, proteins, etc.

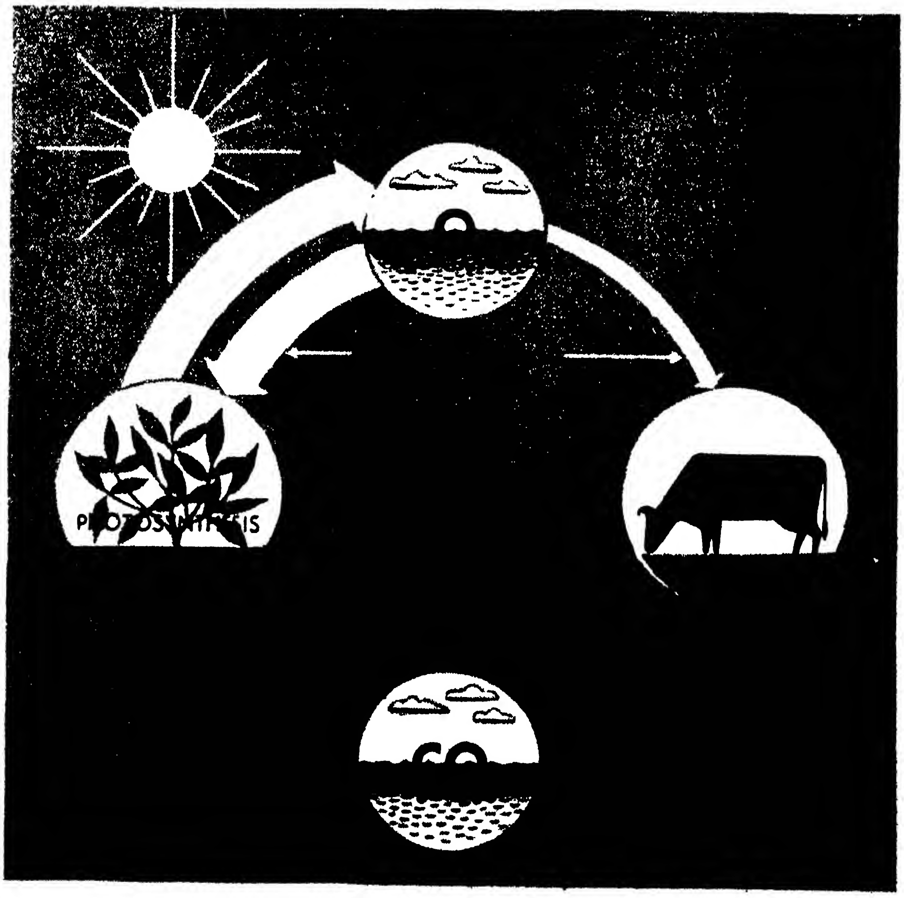
The first study seemed to be simpler and to provide a natural entering wedge for the tracer analysis of photosynthesis. Two groups of researchers connected with the Radiation Laboratory at the University of California have attempted it. Samuel Ruben (who died in a research accident during the war) and his co-workers used the short-lived C^{11}; more recently, Melvin Calvin and co-workers used the long-lived C^{14}. The results appeared promising. It was found that radioactive CO_2 was taken up by plants in the dark. At first it seemed as if this uptake consisted in the addition of carbon dioxide without reduction to a large organic molecule, leading to the formation of an organic acid, as was suggested above. In more recent experiments, however, radioactive carbon has been found in many different fractions, including partly or completely reduced ones, such as proteins or sugars. Since the amount taken up was much greater when the plants were illuminated before being exposed to radioactive carbon dioxide in the dark, Calvin suggested that the whole reduction sequence is a dark reaction; in other words, that in light chlorophyll forms some powerful, unknown reducing agent, which then reduces carbon dioxide all the way to carbohydrate without the help of light.

This hypothesis conflicts with some well-established facts. It has been observed, for example, that manometric (pressure) measurements can detect no significant carbon dioxide uptake or oxygen liberation by plants after they are deprived of light. Moreover, another possible explanation of Calvin's results has developed recently: it has been discovered that many metabolic processes in animal tissues as well as in plants involve absorption of carbon dioxide. At the December A.A.A.S. meeting in Chicago, many critics of the Calvin hypothesis suggested that the phenomena observed at Berkeley belonged in this class, and had nothing to do with photosynthesis.

A group of workers at the University of Chicago—Hans Gaffron, A. H. Brown and E. W. Fager—have used a second approach, tracing the products formed in light, and obtained less controversial results. They studied the distribution of C^{14} in the plant after a period of illumination, and found that the shorter this period, the more pronounced was the concentration of radioactive carbon in a certain chemical fraction of the plant material—the fraction characterized by solubility in water and lack of solubility in alcohol. The striking thing about the unknown radioactive compound concentrated in this



HYDROGEN AND OXYGEN, like carbon, traverse endless cycles in photosynthesis. Plants (*left*) take up water to obtain hydrogen, release water vapor. Animals (*right*) consume plant compounds (*bottom arrow*) and give off water. In diagram below, plants release oxygen in photosynthesis, take it up in respiration and decay. Animals use oxygen, release carbon dioxide.



TRACER EXPERIMENT in the laboratory of Melvin Calvin and Andrew Benson at the University of California begins with the culture of alga *Scenedesmus* in glass flasks. Moving table shakes the flasks above a light source.

ALGAE IN FLASK are supplied by pipette with radioactive carbon in the form of sodium carbonate. Algae grow briefly, using radioactive carbon dioxide released in water. Lights are then shut off and the algae killed.

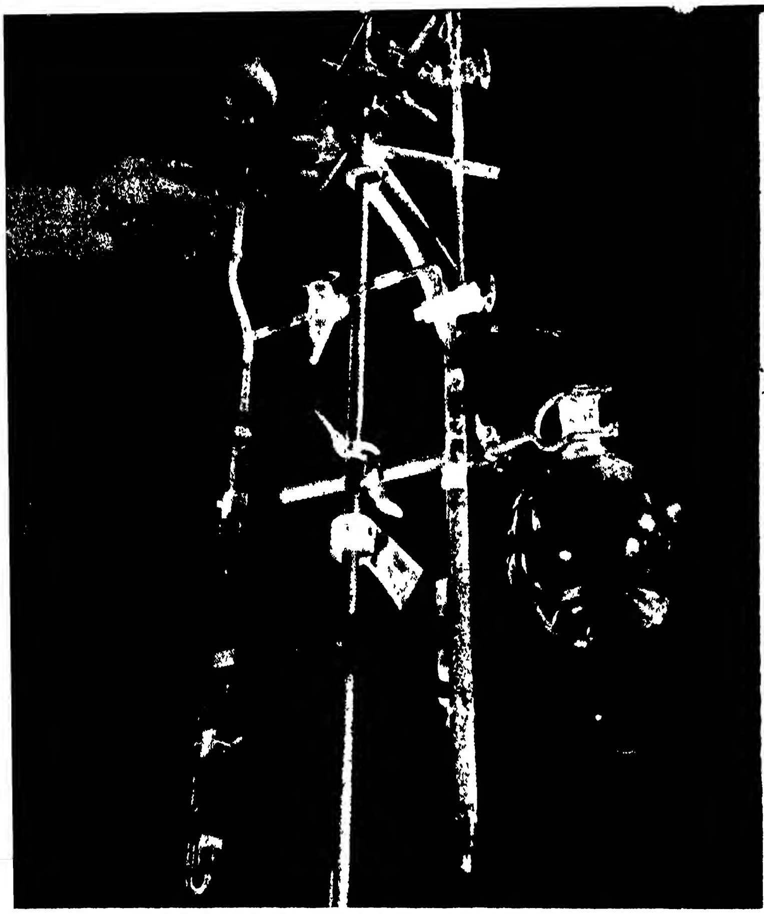
fraction was that it did not budge from the fraction even after hours of dark metabolism; on the other hand, the radioactive carbon passed rapidly into other fractions if light was again thrown on the plants. Here, then, was a true CO_2-reduction intermediate, the first such compound definitely pinned down in a laboratory. The next task is to isolate and identify the new compound. All researchers interested in photosynthesis are looking forward with great anticipation to the result of this tedious but very important analytical investigation.

The isotope O^{18} was employed in a study of photosynthesis by Samuel Ruben and Martin Kamen before the war, and a very significant result was obtained. Using CO_2 and H_2O containing heavy oxygen, they showed that all the oxygen liberated in photosynthesis originated in water; none came from carbon dioxide. (This is a fine example of information that only isotopic tracers can provide!) Their finding was consistent with the hypothesis that photosynthesis is fundamentally a transfer of hydrogen atoms from water to carbon dioxide, with the oxygen left behind.

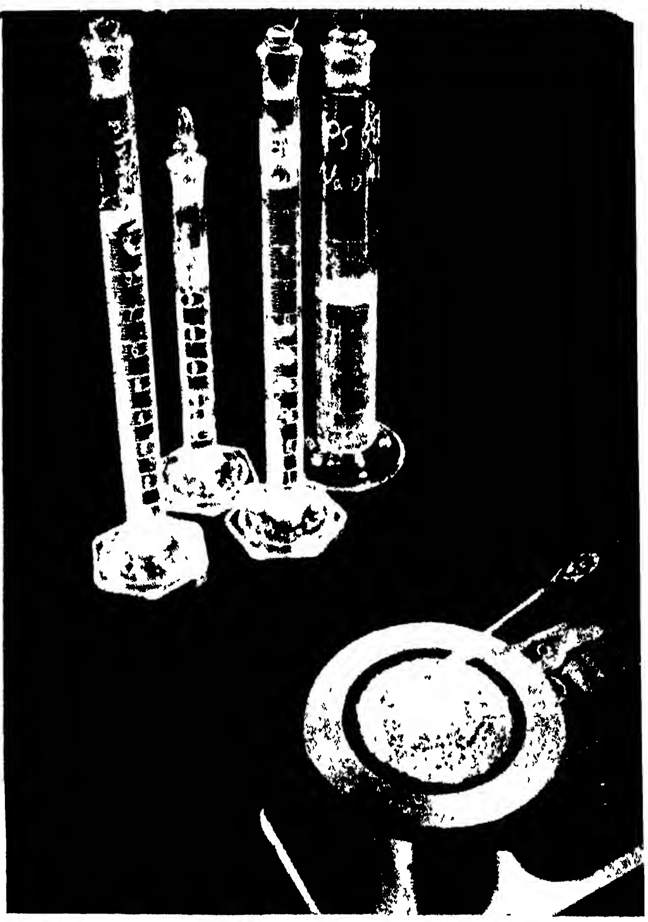
The Mechanism Is Taken Apart

Of all our recent glimpses into the mysterious mechanism of photosynthesis, none appears more promising than the one which was made possible by a discovery made in 1937 by R. Hill of Cambridge University. It had been known for a long time that dried and powdered leaves, when suspended in water and illuminated, sometimes release a small amount of oxygen, although of course they produce no carbohydrates. Hill found that the oxygen production could be increased and sustained for an hour or more if the suspension was provided with a supply of ferric oxalate or some other ferric salt. Later studies by others showed that ferric salts could be replaced by quinone or by certain dyes. All these compounds have one thing in common: they are all rather strong oxidants. They accept hydrogen atoms much more readily than carbon dioxide does. The most plausible interpretation of the results is that when leaves are dried and powdered, a product is obtained which still contains the chlorophyll bridge and the enzymatic system required to produce free oxygen (the right leg in our schematic diagram), but which has lost the left leg's enzymatic system. The suspension therefore can oxidize water and liberate oxygen in light, but it cannot reduce carbon dioxide and produce carbohydrate. Without the aid of enzymes, the carbon dioxide is unable to perform its job of "accepting" hydrogen, but the reaction is kept going by substituting a more willing acceptor (*e.g.*, ferric iron) for carbon dioxide.

Thus we have, in effect, photosynthesis without carbon dioxide! Microscopic studies yield further pertinent evidence.

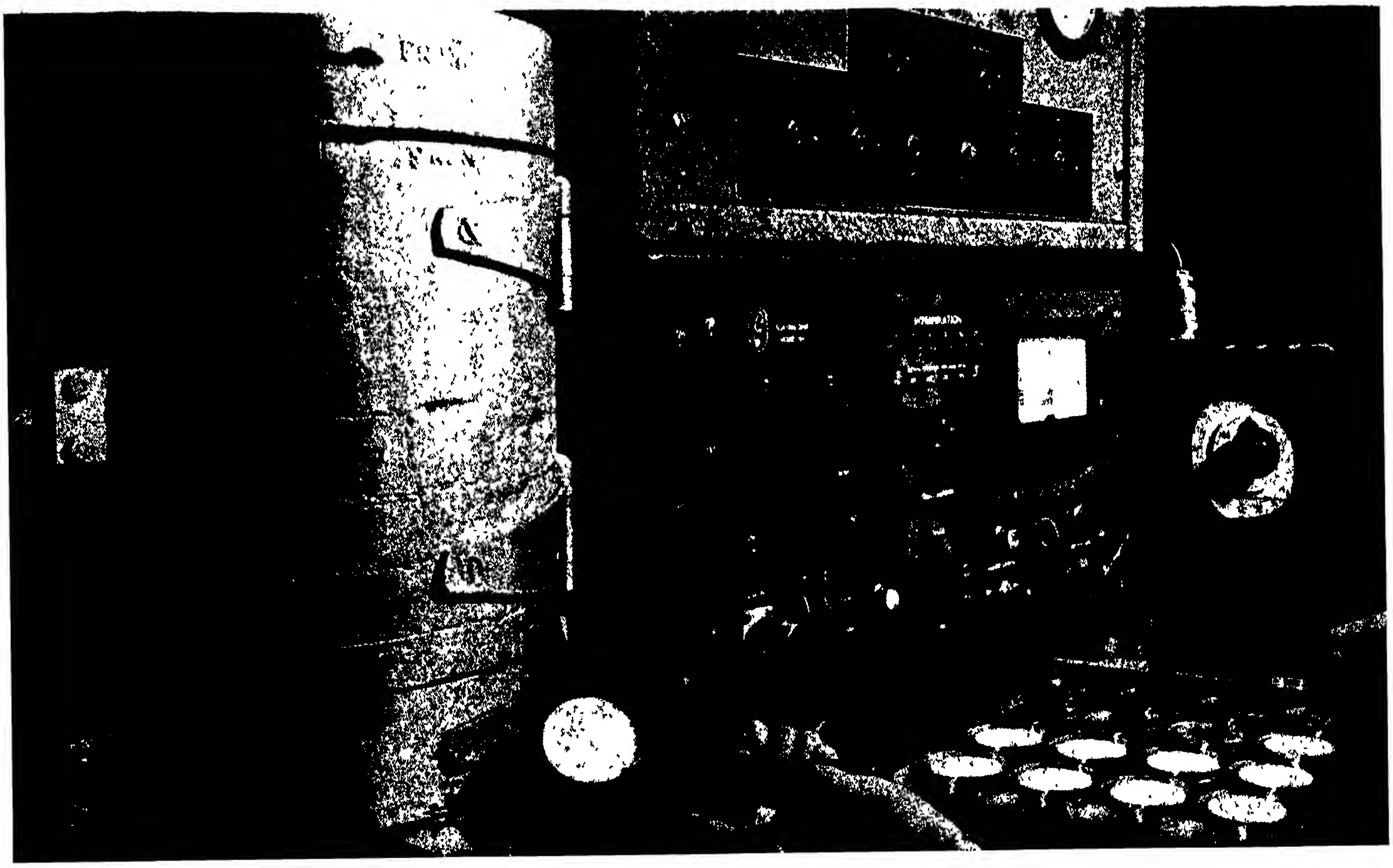


FILTRATE of dead algae is fractionated by passage through ion-exchange tube. Tiny amounts of each fraction are thus available for an analysis of radioactivity.



FRACTIONATED PRODUCT of photosynthesis is placed on aluminum plate and evaporated by electric heater. Residue now remains for examination in counter.

GEIGER-MULLER COUNTER is used to ascertain the relative radioactivity of various aluminum-plate residues. The counter tube is housed within the lead cylinder at the left to shield tube from incidental radiation. Aluminum plates are placed in tray and pushed into cylinder. Counts are recorded by a device at the right.



The photosynthesizing cells of almost all plants contain chlorophyll (and accompanying pigments) in microscopic bodies called chloroplasts. Closer observations have revealed that the pigments are further concentrated within the chloroplasts in tiny "grana," almost too small to be seen under ordinary microscopes but beautifully revealed under the electron microscope. Analysis of the Hill suspension shows that its particles are whole or broken chloroplasts or isolated grana. The grana, then, are the "bricks" in the catalytic structure of photosynthesis which permit the liberation of oxygen from water in light but do not contain the enzymes needed to take up and reduce carbon dioxide. The essential independence of the two enzymatic systems thus receives striking confirmation.

The "Hill reaction" is perhaps the widest crack that has yet appeared in the former picture of photosynthesis as a unique and indivisible process. We have lifted the hood and taken out the motor and it still runs, even though it has to be supplied with a fuel other than the usual gasoline.

It has not yet been possible to perform the converse of this feat: *i.e.*, to eliminate the right leg of the photosynthetic apparatus and keep the left leg functioning. However, something closely related to this has been found to occur in nature: organisms capable of reducing carbon dioxide in light, but unable to use water as a reductant. As substitutes, these organisms use hydrogen sulfide, thiosulfate, or even free molecular hydrogen.

Certain species of bacteria, purple or green in color, contain a pigment called bacteriochlorophyll which is closely related to the chlorophyll of green plants. They thrive in sulfur waters or other media containing reducing agents. Cornelius B. van Niel, the Dutch microbiologist now at Hopkins Marine Laboratory in California, has shown that they can build their organic matter from inorganic materials in light. He suggests the following general chemical equation for their photosynthesis:

$$2RH_2 + CO_2 \xrightarrow[\text{light}]{\text{bacteriochlorophyll}} [C(H_2O)]_2 + 2R.$$

This equation is similar to the one usually given for photosynthesis of green plants, but it is more general, since R can stand for many different radicals, consisting of a single atom or a chemically unsaturated group of atoms. If R is taken as representing an oxygen atom, we have plant photosynthesis; if it is taken to represent an atom of sulfur, we have the photosynthesis of "sulfur bacteria," and so on.

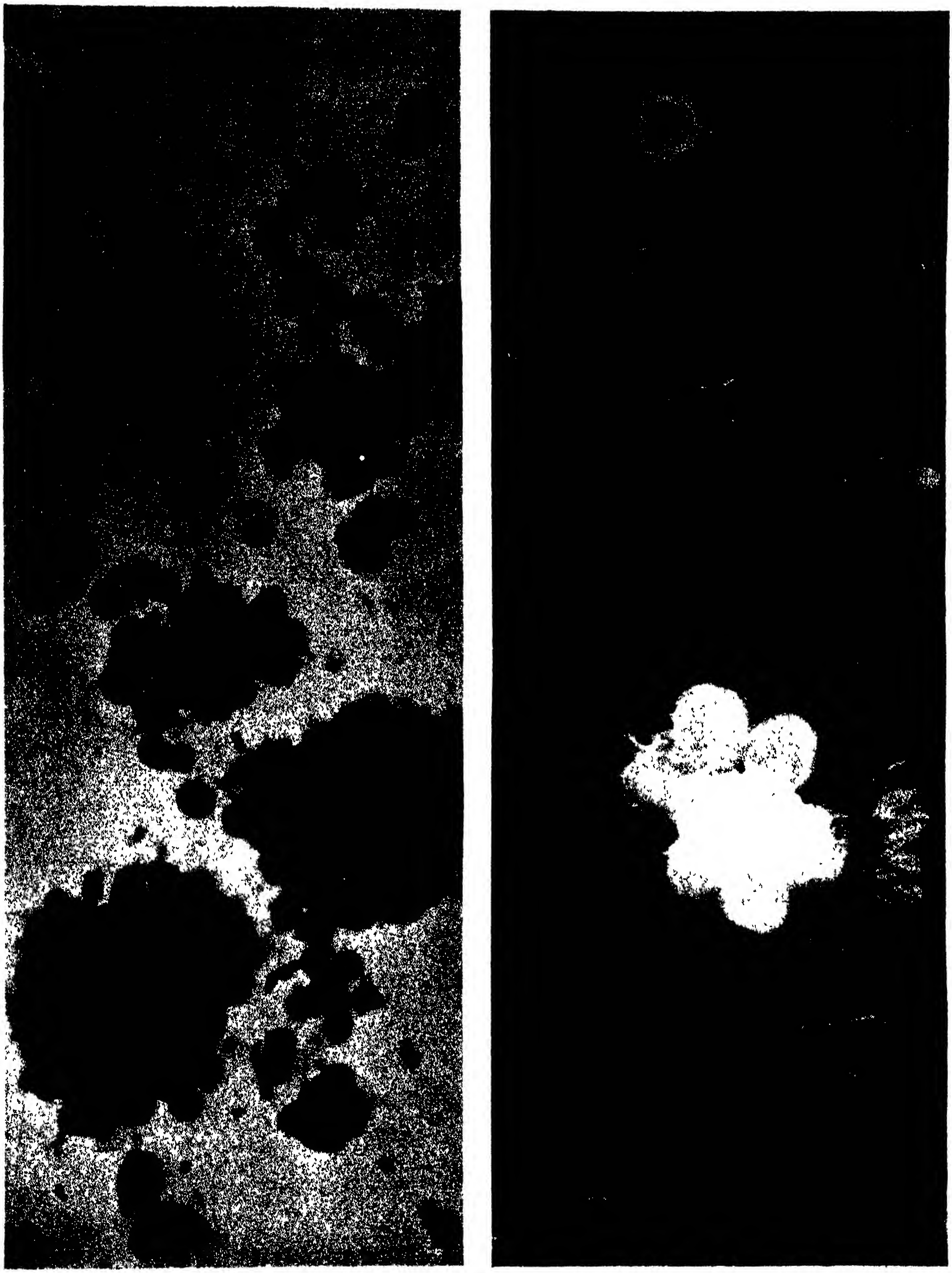
With one stroke van Niel's interpretation of the chemical activity of purple bacteria has removed photosynthesis by green plants from its entirely unique position in biological chemistry and placed it alongside other types of "photosynthetic" processes. Does this discovery indicate that the purple and green bacteria are predecessors of green plants, relics of a time when life was restricted to those places on earth where inorganic reductants were present? A time, perhaps, when the earth's crust was less well stabilized chemically than it is now, and hydrogen sulfide, sulfur, or perhaps even free hydrogen were available in much more abundance?

FURTHER exciting vistas are opened by the similarity of the photosynthetic purple bacteria to some colorless bacteria which are capable of reducing carbon dioxide by means of the same or similar reductants but without the help of light. They use instead the chemical energy liberated by enzymatic oxidation of these reductants by the oxygen of the air. This phenomenon is called bacterial chemosynthesis; it, too, may be a relic of the more primitive forms of life. Hans Gaffron found in 1939 that if certain unicellular green algae are deprived of oxygen, they cease to be capable of ordinary photosynthesis but become capable of reducing carbon dioxide in light if hydrogen is provided as a substitute reductant to replace water! It looks as if lack of air causes these algae to simulate purple bacteria, which also can use hydrogen as reductant.

In photosynthesis, we are like travellers in an unknown country around whom the early morning fog slowly begins to rise, vaguely revealing the outlines of the landscape. It will be thrilling to see it in bright daylight!

EFFICIENCY of *Chlorella* in using light is measured by Robert Emerson and Shimpe Nishimura at the University of Illinois. Monochromatic light separated by slit from spectrum at right is beamed on a vessel containing the alga. Researchers then jointly measure its oxygen output with manometer.

Eugene I. Rabinowitch, author of the textbook Photosynthesis, *is research professor of botany at the University of Illinois.*



"GRANA" OF PLANT CELL, tiny disks containing chlorophyll, are revealed in electron microscope photograph made by S. Granick and K. R. Porter of Rockefeller Institute. In picture at left, grana magnified 6,300 times are loosely grouped in chloroplasts. In picture at right, grana shadowed with gold film and magnified 16,300 times appear as white wafers. Experiments show that release of oxygen from water goes on in grana.

IN DEFENSE OF BENJAMIN FRANKLIN

The homely Philadelphian, often treated by historians as a politician with a spare-time interest in gadgets, was actually one of the great experimental scientists

by I. Bernard Cohen

ALTHOUGH almost every aspect of Benjamin Franklin's career has been subjected to the microscopic examination of critical scholarship, his place in the history of science, as described in books on American history, remains curiously distorted. In his own lifetime, Franklin was generally acknowledged by contemporary scientists to be one of the truly great scientific luminaries of the age. Joseph Priestley declared that Franklin's book on electricity bade fair "to be handed down to posterity as expressive of the true principles of electricity; just as the Newtonian philosophy is of the true system of nature in general." Franklin was awarded every scientific honor that his contemporaries had the power to bestow. One review of his book, comparing Franklin's writings with Newton's famous *Principia Mathematica*, averred that "the experiments and observations of Dr. Franklin constitute the *principia* of electricity, and form the basis of a system equally simple and profound."

Most writers today, however, either stress Franklin's practical inventions or deny altogether his claim to a place among the great founders of pure science. Typical of the latter point of view is an article that appeared a year ago in the journal *Science*, wherein the author declared that the only reason Franklin is sometimes said to be a great scientist and is occasionally listed in the company of the truly great, such as J. Willard Gibbs and A. A. Michelson, is that he was important in American political history!

All too many discussions of Franklin's scientific career center upon the one contribution that almost everyone knows about: his proof, by the experiment of flying a kite during a storm, of the theory that lightning is electrical in nature. Some, indeed, would deny him even this distinction. The author of an article in a learned journal some months ago argued that the story of the lightning kite had been made out of whole cloth by spinners of legends—despite the fact that Franklin published an account of that experiment, which other scientists then repeated, in the leading scientific journal of the day.

But let us forget the kite. It was a comparatively unimportant episode in Franklin's career. It was not the first experiment he designed to test the hypothesis of the electrical nature of the lightning discharge. Neither was it the first experiment that proved this hypothesis, nor was this particular hypothesis original with Franklin. Benjamin Franklin's place in the history of science rests on surer foundations, among them the vast accumulation of new facts of nature that he uncovered by his extraordinary skill in designing and executing experiments, plus his genius in constructing the first satisfactory unitary theory of electrical action. Furthermore, his consummate success gave the art of experimentation itself a new dignity that was wanting in the 18th century. The principles of electricity that he expounded in his book, *Experiments and Observations on Electricity Made at Philadelphia in America*, are part of the very fiber of electrical theory today. We constantly pay Benjamin Franklin an honor of which we are probably not even aware when we use the words "plus" and "positive," or "minus" and "negative," "electrical battery," and a host of other terms that Franklin was the first to apply to electrical phenomena.

FRANKLIN SEAL was affixed to a letter he wrote in 1750. It bears the legend "Je les unis." (I unite them.)

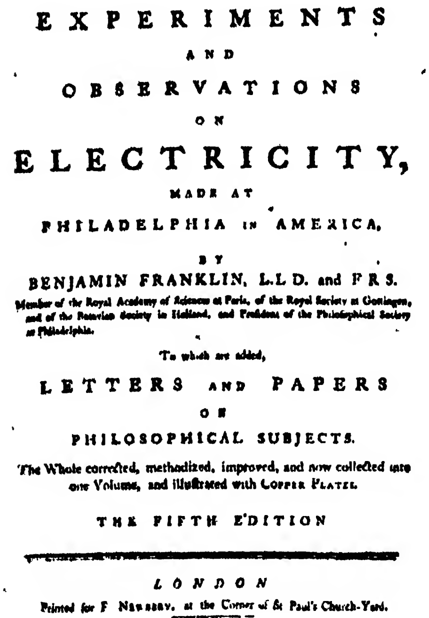
Franklin's treatise on electricity was one of the most widely reprinted scientific books of the mid-18th century. There were five editions printed in English, three in French, one in Italian, one in German. So great was Franklin's scientific reputation that he was elected a Fellow of the Royal Society and awarded its Copley Medal for his experiments in electricity, and in 1773 he was elected one of the eight "foreign associates" of the Royal Academy of Science in Paris. In an age in which scientific accomplishment was esteemed perhaps even more than in our own, Franklin's book was widely studied and his name was on every tongue.

FRANKLIN first became acquainted with the subject of electrical science sometime around 1744. Between 1747 and 1751 he made his major discoveries and began to win scientific acclaim. Contrary to the supposed general rule that the great discoveries in physics are made by men in their twenties and thirties, Franklin began his scientific work at about the age of 40; he had previously been too busy earning a living to devote much time to scientific pursuits. Having been successful in the world of affairs and now finding the pursuit of truth congenial to his tastes and gifts, he decided, as he tells us in his autobiography, to give up his business and to spend his time making experiments. No sooner had he retired from business, however, than a great national crisis arose and he put aside his scientific research in order to participate in the defense of Philadelphia. From then on until he died, he pursued his research only in his spare time. His city, colony and nation never ceased to require his services. At 81 years of age, when his work at Paris was finished and he was ready to come home to America, Franklin wrote to his most intimate scientific cor-

PORTRAIT OF FRANKLIN was engraved from a painting made in France, where he was a noted public figure. Even before he arrived in 1776 to plead the cause of the American Revolution, Franklin was known in France as a scientist and philosopher. In 1773 he had been made an associate of the Royal Academy of Science.

respondent, the Dutch physician Jan Ingen-Housz, that he was once more a free man "after fifty years in public affairs." He hoped that his friend would come with him to America, where "in the little remainder of my life . . . we will make plenty of experiments together." Alas, even this was to be denied him, for ahead there lay not days of joyful interrogation of nature but the trying and tedious work of the Constitutional Convention. Long before, Franklin had been forced to choose between the role of a quiet philosopher and a "public man." He had decided the issue without hesitation, saying: "Had Newton been pilot of but a single common ship, the finest of his discoveries would scarce have excused, or atoned for his abandoning the helm one hour in time of danger; how much less if she carried the fate of the Commonwealth."

As we read these lines today, we cannot help thinking of our own scientists who, during the late war, gave up their own individual research to serve their nation. But there is a fundamental difference between their problem and Franklin's. In Franklin's day the one outstanding American scientist, the only one with a world-wide reputation, found that he could serve his country best by going abroad to plead its cause, rather than by



EXPERIMENTS

AND

OBSERVATIONS

ON

ELECTRICITY,

MADE AT

PHILADELPHIA IN AMERICA,

BY

BENJAMIN FRANKLIN, L.L.D. and F.R.S.

Member of the Royal Academy of Sciences at Paris, of the Royal Society at Gottingen, and of the Batavian Society in Holland, and President of the Philosophical Society at Philadelphia.

To which are added,

LETTERS AND PAPERS

ON

PHILOSOPHICAL SUBJECTS.

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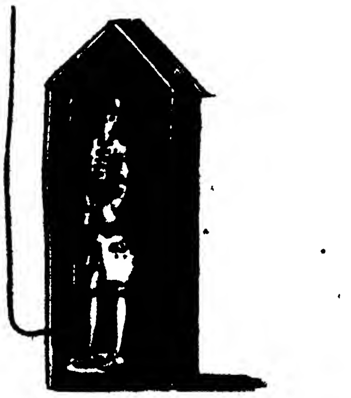
MDCCLXXIV.

FRANKLIN'S BOOK on electricity was held in high esteem by contemporary scientists. It was compared with Sir Isaac Newton's *Principia*.

applying his scientific skills to devising new instruments of destruction. Yet such was Franklin's stature in science—and he was the Newton of his age—that some suspected the man who dared to tame the lightning bolts of Jove had turned his talents to the perfection of a new and terrible weapon. "The natural philosophers in power," wrote Horace Walpole in 1777, "believe that Dr. Franklin has invented a machine of the size of a toothpick case, and materials that would reduce St. Paul's to a handful of ashes."

Benjamin Franklin made scientific contributions in many fields, including pioneer studies of heat conduction, the origins of storms, and so on, but his most significant work was done in electricity. He worked in electrostatics—the science of electricity at rest or in sudden swift surges. Before



"SENTRY BOX" experiment was devised by Franklin to test his theory that lightning was electrical in nature. It was first performed in France.

Franklin, the known facts of this subject were meager and their explanation was inadequate. When he left the field, a whole new set of observed data had been entered in the record and the Franklinian theory of electrical action had unified all the known facts, preparing the way for the progress of the future.

FRANKLIN'S theory of electrical action is simple and straightforward. It is based on the fundamental idea that there is "common matter," of which the bulk of bodies is composed, and "electrical matter," or, to use other 18th-century terms, "electrical fluid" or "electrical fire." In its normal state, every body contains a fixed amount of the electrical fluid. But a body may, under certain conditions, gain an excess of the electrical fluid or lose some of its normal complement of it. In such a state a body is "electrified" or "charged"; in the first case, when there is an excess of the fluid, said Franklin, let us call the charge "positive" or "plus," indicating that something has been added to it; in the second case, let us call it "minus" or "negative," indicating that something has been lost. When we rub a piece of glass with a silk rag, the glass acquires an excess of the electrical fluid and becomes charged plus. Franklin insisted that electricity was not "created" by friction, as many of his contemporaries believed, but rather was redistributed by the act of rubbing. If the glass gains an excess of fluid, the silk must have lost the very same amount, thereby gaining a negative charge of the same magnitude. Today we call this principle the law of conservation of charge.

Franklin illustrated his theory by the following experiment. He placed two experimenters on insulated glass stools, one charged plus and the other minus. When the two experimenters touched hands, both lost their charge because the excess of one supplied the deficiency of the other. If a third uncharged experimenter touched either of the charged ones, he drew a spark or got a shock, because he had relatively more electric fluid than the man charged minus, and less than the man charged plus.

This was a simple, dramatic demonstration of Franklin's contention that electricity was a single fluid. The chief rival theory held that there were two electrical fluids, which sometimes moved in "efflux" and at other times in "afflux," and which operated by some mysterious rules that were never made clear. A French contemporary pointed out that the beauty of Franklin's theory over its rival was that "Franklin says: do that and this is what must happen; change that circumstance and this will be the result. In this way you can take advantage of a certain thing; in that way you will suffer an inconvenience." The late J. J. Thomson, discoverer of the fundamental properties of moving electrons, wrote only a few years ago: "The service which Franklin's one-fluid theory has rendered to the science of electricity by suggesting and coordinating re-

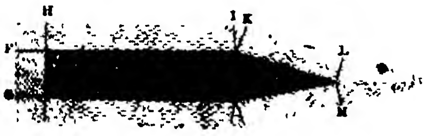
EXPERIMENT with bent wire (a), linen thread (b) and "electrized phial" (c) noted that thread was attracted to phial when latter was touched.

searches can hardly be overestimated."

To understand the application of Franklin's theory, let us follow him through two series of significant experiments. The first begins with one of the many facts first discovered by Franklin and now part of the basic data of the science—the "wonderful effect of pointed bodies, both *drawing off* and *throwing off* the electrical fire." Franklin found that if a pointed conductor such as a needle is brought into the neighborhood of a charged insulated body, the needle will draw off the charge; but it will do so only if it is grounded, that is, in contact with the hand or a grounded wire. If the needle is inserted in wax, a non-conductor or insulator, it

will not draw off the charge. He also found that if you try to charge a metal object with a jagged edge or point, the object will "throw off the charge" as fast as you put it on. He discovered further that a charged object could be discharged by sifting fine sand on it, by breathing on it, by bringing a burning candle near it, or by surrounding it with smoke.

FOR AT LEAST 50 years before Franklin's research people had speculated that lightning was probably electrical. But what distinguished Franklin from his predecessors was the fact that he was able to design an experiment to test this hypothesis. He made a small model showing how a discharge might take place between two electrified clouds or between



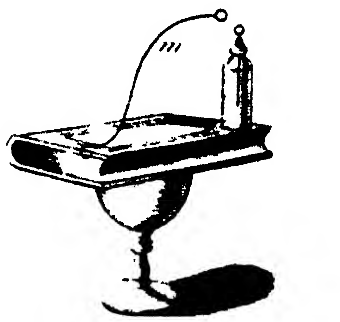
THEORY of why electric charge tends to jump from the pointed parts of a charged object was set forth by Franklin in drawing from his book.

a cloud and the earth. He then pointed out that since a small pointed conductor could draw off the charge from an insulated charged body in his laboratory, a large pointed conductor erected in the ground might very well draw the electricity from passing clouds. This suggested to his active mind that "the knowledge of this power of points might be of use to mankind, in preserving houses, churches, ships, &c., from the stroke of lightning, by directing us to fix on the highest parts of those edifices, upright rods of iron made sharp as a needle, and gilt to prevent rusting, and from the foot of those rods a wire down the outside of the building into the ground, or down around one of the shrouds of a ship, and down her side till it reaches the water."

The experiment which Franklin proposed to test his hypothesis was described by him in these words: "On the top of some high tower or steeple, place a kind of sentry-box . . . big enough to contain a man and an electrical stand. From the middle of the stand let an iron rod rise and pass bending out of the door, and then upright 20 or 30 feet, pointed very sharp at the end. If the electrical stand be kept clean and dry, a man standing on it when such clouds are passing low, might be electrified and afford sparks, the rod drawing [electrical] fire to him from a cloud. If any danger to the man should be apprehended (though I think there would be none) let him stand on the floor of his box, and now and then bring to the rod the loop of a wire that has one end fastened to the leads, he holding it by a wax handle; so the sparks, if the rod is electrified, will strike from the rod to the wire, and not affect him."

This famous "sentry-box experiment" was first performed in France on May 10, 1752 by a man named Dalibard, who had translated Franklin's book into French at the request of the great naturalist Georges de Buffon. (King Louis XV was so fascinated by Franklin's book that he ordered some of the experiments it described to be performed in his presence.) The experiment was soon repeated in England. Glowing testimonials to the Philadelphia scientist speedily increased in number. An enterprising British manufacturer advertised for sale a ready-made machine "for making the Experiment by which *Franklin's* new theory of Thunder is demonstrated." Franklin did not make the experiment himself because he thought that a very high building would be necessary and he was waiting for the completion of the high spire on Christ Church in Philadelphia. After the book was published, but before he had heard from Europe of Dalibard's successful execution of the experiment, the kite project occurred to him as a good substitute and he carried it through instead.

FRANKLIN devised other experiments and instruments to test the charge of clouds, of which one of the most interesting was a pair of bells located in his study. One of the bells was grounded by a rod going into the earth and the other was connected with a rod ending in a point on the roof. A little ball hung between them

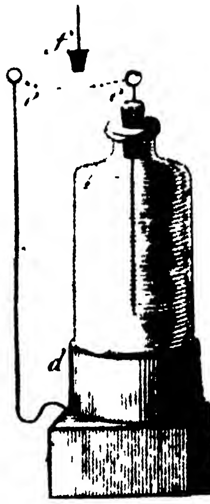


"ELECTRICAL FIRE" of the Leyden jar was made visible when it was allowed to flash along the gold embossing of one of Franklin's books.

Whenever an electrified cloud passed overhead, the ball was set in motion and rang the bells. Franklin's careful studies soon showed him that clouds may be charged either plus or minus, and he concluded, therefore, that lightning probably goes from the earth to a cloud at least as often as from a cloud to the earth—an idea which has been confirmed only in our own time by such research as that of B. J. F. Schonland and his associates in South Africa.

Franklin's studies of lightning and his invention of the lightning rod brought him universal fame, but the scientists of his day were perhaps even more impressed by his analysis of the electrical condenser, which set the seal to his scientific reputation.

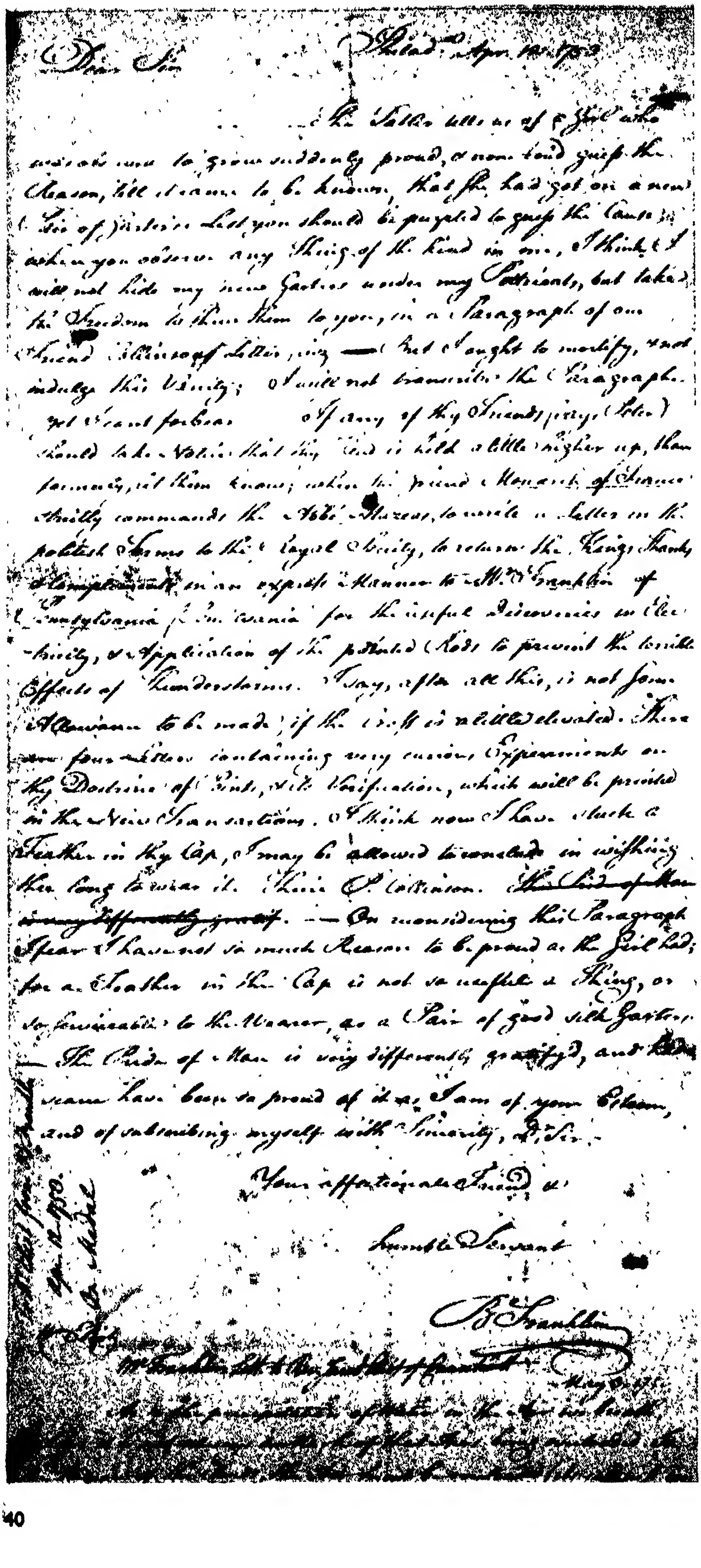
In the form that the 18th century knew it, the condenser was a glass jar coated on the outside with metal foil and filled with either metal shot or water. It was fitted with a wooden cover into which a rod ending in a knob was inserted. From the lower end of the rod a metal chain depended, going down into the water or shot. This device, invented in the late 1740s, was known as a "Leyden jar," because one of its several independent discoverers, Pieter van Musschenbroek, was



LEYDEN JAR discharge was investigated by hanging cork between poles. Cork oscillated during discharge, a useful fact in condensers.

a professor in Leyden. The essential feature of a condenser is the placement of an insulator or dielectric (*e.g.*, air, glass, wax or paper) between two conducting surfaces in close contact with it. In the first Leyden jar the inner conductor was water, the dielectric was the glass and the outer conductor was a man's hand. Musschenbroek developed his version of it while carrying out some experiments with an electrical machine which charged a whirling glass globe by rubbing it against an experimenter's hands. The charge was transferred to a gun barrel, from the end of which hung a wire that was partly immersed in a round glass vessel filled with water. When Musschenbroek held the vessel in his right hand and attempted to draw a spark from the gun barrel with his left hand, he "was struck with such violence that my whole body was shaken as by a thunderbolt . . . . in a word, I thought it was all up with me."

The condenser was a wonderful instrument. By making it bigger and bigger, the shocks it could give were made stronger and stronger. Apparently, somehow or other electricity accumulated in it, and through some little-understood aspect of its construction, it could hold more elec-



LETTER Franklin wrote to a friend in 1753 tells of his pleasure at receiving the notice of the French court and the Royal Academy of Science. In it Franklin mentions his friend Thomas Collinson, who first sent him from England the wonderful Leyden jar invented by Pieter van Musschenbroek (*opposite page*). Franklin was elected to the French Academy some 20 years later.

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Philadelphia
April 12, 1753

Dear Sir

The Tatler tells us of a girl who was observed to grow suddenly proud, and none could guess the Reason, till it came to be known, that she had got on a new Pair of Garters. Lest you should be puzzled to guess the Cause, when you observe any Thing of the kind in me, I think I will not hide my new Garters under my Petticoats, but take the Freedom to shew them to you, in a Paragraph of our Friend Collinson's Letter, viz—But I ought to mortify, and not indulge this Vanity;—I will not transcribe the Paragraph—yet I cant forbear.—"If any of thy Friends (says Peter) should take Notice that thy Head is held a little higher up, than formaly, let them know; when the *Grand Monarch of France* strictly commands the *Abbé Mazeas*, to write a Letter in the politest Terms to the *Royal Society*, to return the Kings Thanks and Compliments in an express Manner to *Mr. Franklin* of *Pennsylvania* (Pensilvania) for the useful Discoveries in Electricity, and Application of the pointed Rods to prevent the terrible Effects of Thunderstorms. I say, after all this, is not some Allowance to be made, if the Crest is a little elevated. There are four Letters containing very curious Experiments on thy Doctrine of Points, and its Verification, which will be printed in the New Transactions. I think now I have stuck a Feather in thy Cap, I may be allowed to conclude in wishing thee long to wear it. Thine P. Collinson."—On reconsidering this Paragraph I fear I have not so much Reason to be proud as the Girl had; for a Feather in the Cap is not so useful a Thing, or so serviceable to the Wearer, as a Pair of good silk Garters.—The Pride of Man is very differently gratify'd, and had scarce have been so proud of it as I am of your Esteem, and of subscribing myself with Sincerity, Dr. Sir.

Your affectionate Friend &
humble Servant
B. Franklin

●

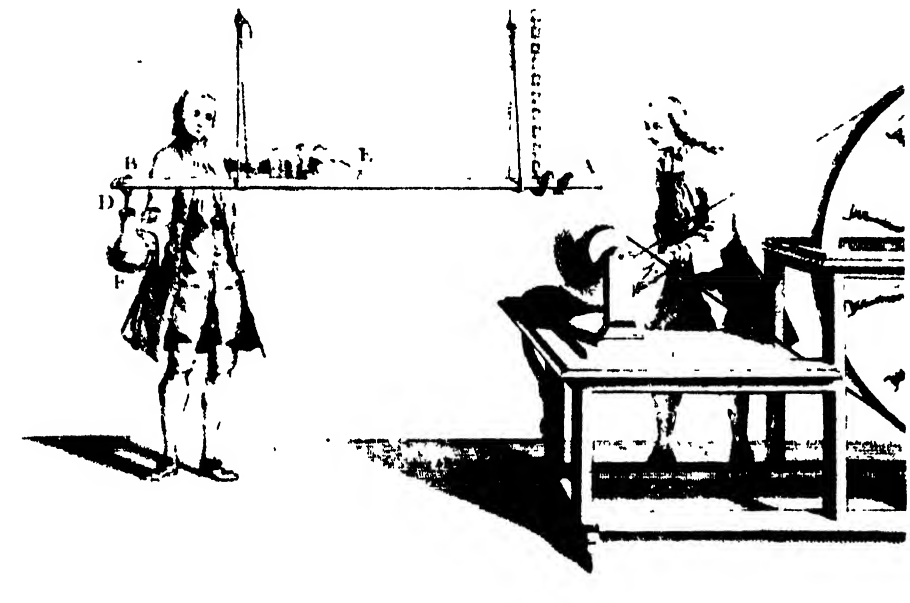
The remaining lines of the letter, a postscript, are not transcribed.

tricity than anything else of its size. The electric fluid or fluids must, it was thought, be condensed in it. Musschenbroek wrote a letter describing this experiment which was published in the *Mémoires* of the French Academy of Sciences. It ended with the famous statement that he would never again receive such a shock, even if he were to be offered the Kingdom of France! For such ignoble sentiments he was publicly rebuked by Priestley, who called him a "cowardly professor" and contrasted him with the "magnanimous Mr. Boze, who with a truly philosophic heroism worthy of the renowned Empedocles, said he might die by the electric shock, that the account of his death might furnish an article for the memoirs of the French Academy of Sciences." Then, referring to one Richman, who had just been killed while performing a variation of Franklin's sentry-box experiment, Priestley concluded, "But it is not given to every electrician to die the death of the justly envied Richman."

ALL THE electricians of Europe wondered what made the Leyden jar work. "Everybody," wrote Priestley, "was eager to see, and, notwithstanding the terrible account that was reported, to *feel* the experiment." In France the new device provided a means of satisfying simultaneously the court's love of spectacles and the great interest in science. One hundred and eighty soldiers of the guard were made to jump into the air with a greater precision than soldiers of the guard displayed in any other maneuvers. Seven hundred monks from the Couvent de Paris, joined hand to hand, had a Leyden jar discharged through them all. They flew up into the air with finer timing than could be achieved by the most gifted corps of ballet dancers. From one end of the world to the other, traveling demonstrators of electrical phenomena made fortunes.

Franklin's step-by-step analysis of the vexing problem of the condenser showed him to be a great master of the technique of scientific experimentation. He found that the inside conductor was always charged in the opposite sign to the outer conductor and that the amount of charge given to both was the same. In other words, after charging of the jar, one of the two conductors gained the exact quantity of "electrical fluid" that the other had lost. "There is really no more electrical fire in the [Leyden] phial after what is called its *charging*, than before, nor less after its *discharging*," Franklin wrote. To prove it, he affixed a wire to the lead coating of a Leyden jar and placed it so that it was near the knob leading to the water inside the jar, but not near enough to produce a spark when the jar was charged. He than placed the jar on an insulating stand, a block of wax, and suspended a small cork on a string between the wire and the knob. The cork, he noted, "will play incessantly from one to the other, 'till the bottle is no longer electrized." In other words, the cork carried the charge from the plus conductor to the minus until equilibrium was restored.

Most important of all, Franklin showed that "the whole force of the bottle, and power of giving a shock, is in the GLASS ITSELF." How would *you*, reader, go about finding "wherein its strength lay"? Every student knows today that the only way to proceed is to test the instrument one element at a time, and to find the role played by each. But this apparently simple rule was not taken for granted in the time of Franklin, as can readily be seen in the fact that his contemporaries failed to make the kind of analysis that



"ELECTRICAL MACHINE" devised by van Musschenbroek consisted of a glass sphere charged when a man held his hands against it. Charge was then carried along a beam to a Leyden jar. When van Musschenbroek attempted to discharge the jar by touching beam, he was shaken "as by a thunderbolt."

Franklin now proceeded to carry out.

He charged a Leyden jar that stood on glass and carefully drew out the cork with its wire that hung down into the water. Then he took the bottle in one hand, and brought the other hand near its mouth. "A strong spark came from the water, and the shock was as violent as if the wire had remained in it, which shewed that the force did not lie in the wire." If it was not in the wire, then perhaps it was in the water itself. Franklin recharged the Leyden jar, drew out the cork and wire as before, and carefully poured the water into an empty Leyden jar which likewise stood on a glass insulator. The second jar did not become charged in this process. "We judged then," Franklin wrote, "that [the charge, or force] must either be lost in decanting, or remain in the first bottle. The latter we found to be true; for that bottle on trial gave the shock, though filled up as it stood with fresh unelectrified water from a tea-pot." Apparently the essential element was glass, the insulator between the two conductors. But it remained to be demonstrated whether "glass had this property merely as glass, or whether the form [of the jar] contributed anything to it."

The next part of the experiment involved the invention of the parallel plate condenser. Franklin sandwiched a large piece of glass between two square plates of lead, equal to each other in size but slightly smaller than the glass. When this condenser was charged, he removed the lead plates, which had but little charge, and noted that a small spark could be taken from the glass at almost any point that it was touched. When the two completely uncharged plates were put back in place, one on each side of the glass, and a circuit made between them, then "a violent shock ensued." When we demonstrate this phenomenon to students today, we call it the experiment of the dissectible condenser. We explain it by stating that the dielectric, or glass, has been polarized during charging, *i.e.*, it has become an electret. There are certain types of wax that can be polarized in this way simply by being heated and then cooled. Such an electret will give off little or no charge by itself, but if we put a conductor on two sides of it, we have a charged condenser which can be then discharged like any other. Another fact about such condensers that we teach students today was also discovered by Franklin: the amount of charge is greater when the dielectric separating the two conductors is very thin than when it is thick.

Franklin's experiment of the cork that traveled back and forth between the two conductors contained, by the way, the germ of an important idea, although he did not realize it. We know today that

a condenser never discharges in one complete stroke, but rather in a series of oscillations—a fact of great importance in radio and modern electronics.

Franklin's extraordinary experiments and his splendid theory marked the beginning of a new era in the subject of electricity. His theory showed its usefulness in many ways. Franklin discovered what is known today as the Faraday effect, namely that the charge on a hollow cylindrical condenser (or a hollow sphere) is on the outside surface only. At first he could not explain this. Later the answer came to him: the "electrical fluid" is self-repellent and the symmetry of the conductor causes it to distribute itself on the outside. From this explanation, Franklin's friend Joseph Priestley deduced that the law of electrical action must be an inverse square law similar to the law of gravitation. This deduction, although published, was overlooked and had to await rediscovery decades later by Charles Coulomb, when it became known as Coulomb's law.

Yet another advantage of Franklin's theory was the ease with which it lent itself to the making of measurements, by concentrating attention on the amount of "electrical fluid" or charge which a body gained or lost. When working with two bodies, it did not matter which one was used, because Franklin's law of conservation of charge meant that the quantity gained by one was exactly the quantity that the other lost. The first electricians to make quantitative measurements—such men as Volta, Bennet, Canton, Cavendish and Henley—built upon the convenient one-fluid theory of Benjamin Franklin, and the law of conservation of charge which followed from it.

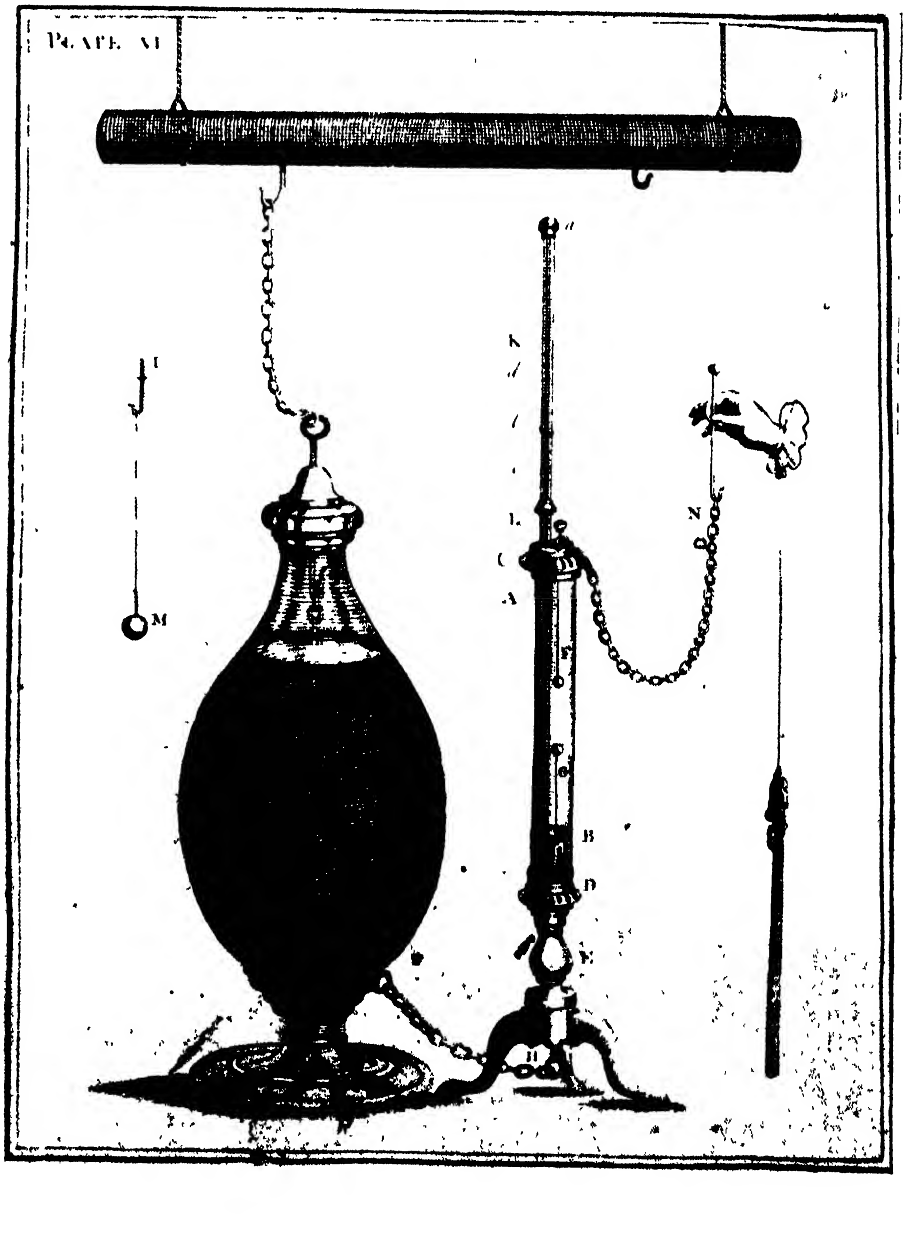
IT IS OFTEN said that Franklin was typically American in his approach to science—a utilitarian interested in science chiefly, if not solely, because of its practical applications. It is true that when he had discovered the action of pointed grounded conductors and proved that clouds are electrified, he applied these discoveries to the invention of the lightning rod. But he did not make these discoveries in order to invent a lightning rod! Franklin's inventions were of two kinds. One type was pure gadgetry; in this class were his inventions of bifocal glasses, which required no recondite knowledge of optical principles, and of a device for taking books down from the shelf without getting up from one's chair. The lightning rod, on the other hand, developed from pure scientific research. If Franklin's approach to science had been strictly utilitarian, it is doubtful that he would ever have studied the subject of electricity at all. In the 18th century there was only one practical application of electricity, and that was the giving of electric shocks for therapeutic purposes, chiefly to cure paralysis. (Although Franklin on occasion participated in such therapy, he did not believe that the shock itself ever cured a case of paralysis. With shrewd psychological insight, he guessed that the reported cures arose from the desire of the patient to be cured rather than from the passage of electric fluid.)

Franklin studied nature because he wanted to discover her innermost secrets, and he chose electrostatics because chance brought him the instruments with which to study this subject, and because he quickly found out that this was a subject well fitted to his particular talents. In a spirit which might well be emulated by all men engaged in research, he wrote humbly at the end of one of his communications: "These thoughts, my dear friend, are many of them crude and hasty; and if I were merely ambitious of acquiring some reputation in philosophy [*i.e.*, natural philosophy, or science], I ought to keep them by me, 'till corrected and improved by time, and farther experience. But since even short hints and imperfect experiments in any new branch of science, being communicated, have oftentimes a good effect, in exciting the attention of the ingenious to the subject . . . you are at liberty to communicate this paper to whom you please; it being of more importance that knowledge should increase, than that your friend should be thought an accurate philosopher."

With the discovery of electrons, protons and neutrons, many modern writers have argued about whether Franklin's one-fluid theory was or was not closer to the modern conception than the two-fluid theory of his rivals. To my mind, such debates are wholly without value. The value of Franklin's contribution to electricity does not lie in the degree to which it resembles our modern theory, but rather in the effect his researches had in getting us along on the road to our modern theory.

At the time that Franklin undertook his studies, the world of science

HEAT OF ELECTRICAL FIRE was proved by this apparatus illustrated in Franklin's book. When charge of Leyden jar at left was allowed to jump between wires F and G in tube, heat was recorded by thermometer.



lay under the spell of Isaac Newton, whose great *Principia* had shown that the motions of the universe could be explained by simple mathematical laws. Newton convinced almost everyone that mathematics and mathematical laws were the only key to the understanding of nature. What many people forgot, however, was that Newton's success in applying mathematical analysis to celestial and terrestial mechanics was possible only because the facts had been accumulated and classified, and were in a state where his great genius could make the first great synthesis of the modern scientific era. But when it came to optics, Newton made no synthesis such as he did for mechanics, nor was he able to reduce his quantitative and qualitative discoveries to the form of general mathematical law. In the field of optics, Newton was but one of the giants upon whose shoulders some later synthesizer was to stand. In contrast with the austere *Principia*, whose motto was *Hypotheses non fingo* ("I frame no hypotheses"), his *Opticks* contained a long set of "queries" in which Newton discussed the possible explanations that might be given to his observed facts. These resemble Franklin's speculations concerning electrical phenomena. In Franklin's time, as with optics in Newton's time, the state of electrical science did not yet permit a full mathematical synthesis. What was required were "giants" to uncover the facts of charge, of induction, of grounding and insulation, of the effect of shapes of conductors and so on, giants to build a workable manipulative theory to unify these facts and to draw attention to essential elements that might be measured. Franklin's success paved the way for the mathematical theorists of the 19th century.

But, even more, his mastery of the technique of experimentation, his successful and consistent explanations in terms of a simple physical conceptual scheme, and the many new and curious facts of nature he revealed, gave experimental science a new dignity in the eyes of his 18th-century contemporaries. The French philosopher Diderot wrote, in his essay on the interpretation of nature, that Franklin's book on electricity, like the works of the chemists, would teach a man the nature of the experimental art and the way to use the principles of experimental research to draw back the veil of nature without multiplying its mysteries.

This was the sense, then, in which Franklin's contemporaries believed him to be the new Newton, and this was the first great contribution made by America to the mind of science. In this light, there can be no doubt of Franklin's stature in science, nor that he deserves to stand as the first American scientist.

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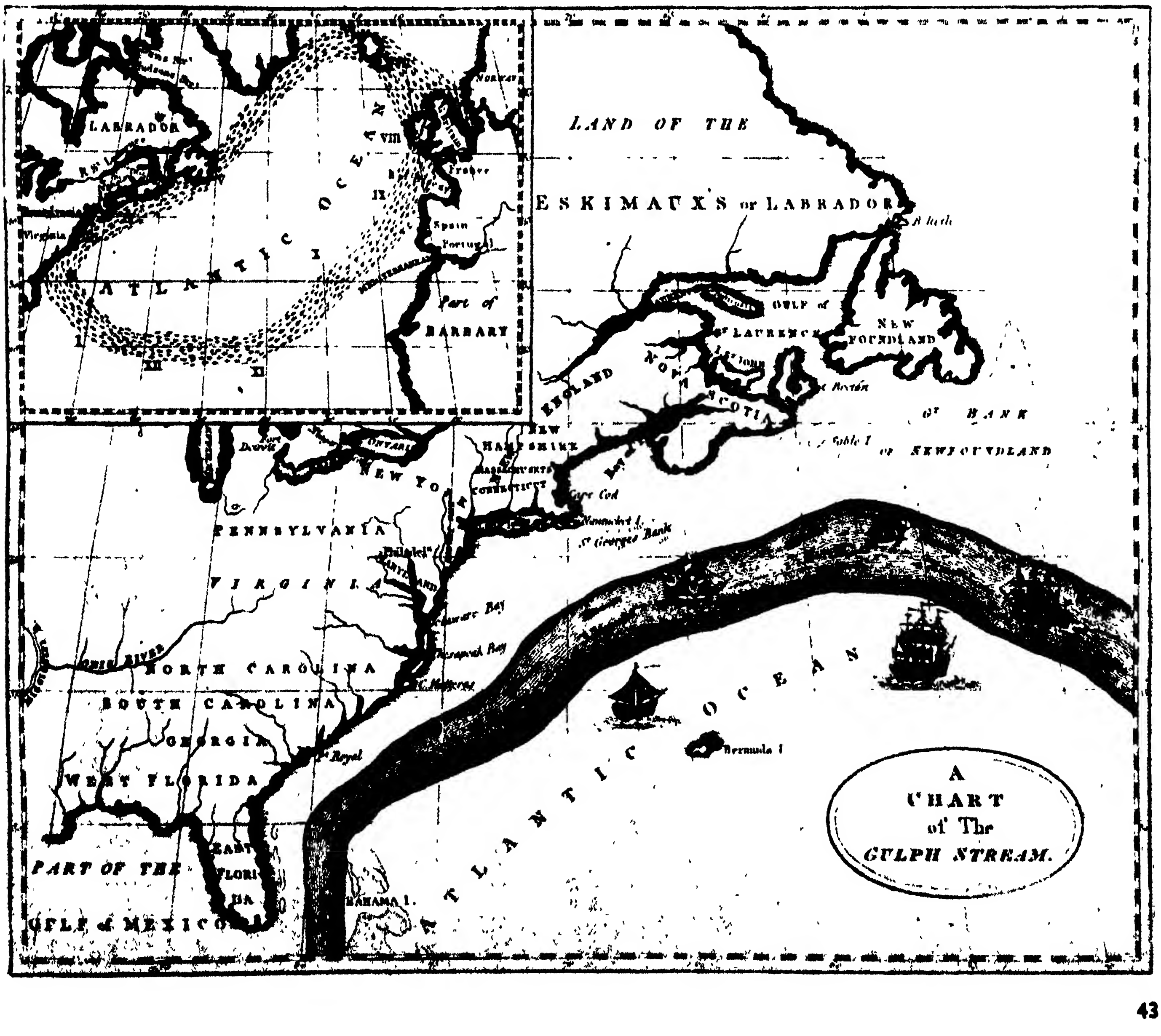
LITTLE-KNOWN WORK of Franklin was the charting of the Gulf Stream. When he was deputy postmaster-general of the colonies, he noted that Rhode Island ship captains shortened their passage from England by cutting across a certain current instead of sailing against it. Franklin extended their knowledge to chart the stream.



HIGH BLOOD PRESSURE

The cause of a fatal constellation of heart and blood-vessel disorders, hypertension is one of man's most critical medical problems

by Irvine H. Page

AMONG physicians and thoughtful laymen there is a growing concern over human vulnerability to high blood pressure and hardening of the arteries. Death certificates show that these associated conditions kill some 600,000 people in this country annually; by 1960, the insurance companies estimate, blood vessel disorders and related diseases of the heart will kill 1,200,000.

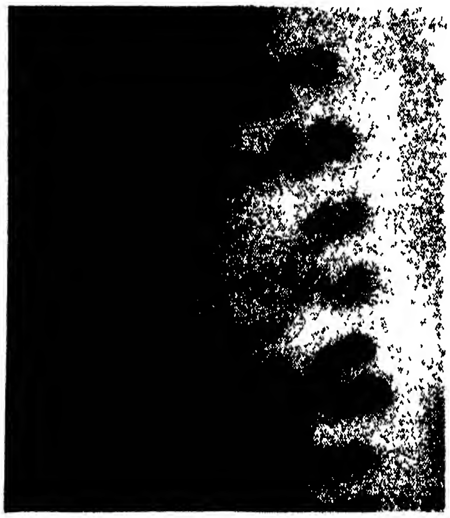
To put it another way, 50 of every 100 children born today will die of these diseases. That is three and one half times as many deaths as from cancer, ten times as many as from tuberculosis, and a thousand as many as from infantile paralysis.

High blood pressure (hypertension) and hardening of the arteries (arteriosclerosis) are not, as commonly supposed, merely the concomitants of growing old. Hypertension is by no means limited to middle-aged and elderly people. It is, for example, fast becoming the greatest killer of pregnant women, and, through them, of unborn children. It is estimated that 2,000 mothers and 16,000 unborn infants die of this cause each year. And of the mothers who survive the hypertension originating in pregnancy, 50,000 come to an earlier death as a result.

The statistics alone are sufficiently appalling, and they do not begin to convey the associated human suffering. Yet the public, strangely, seems far from appalled; either it is unaware of this dread mortality or accepts it fatalistically. Hypertension and arteriosclerosis are not glamorous diseases. They work quietly, progressively, and show themselves only late in their course, Their incapacitating effects are most often clearly perceived during the later years of life—the years of wisdom and maturity, lacking which society is the poorer.

Since the 18th century, life expectancy in the U. S. has increased from 39 to 57 years, largely because of the conquest of diseases such as smallpox, typhoid fever, tuberculosis, plague, infantile dysentery, diphtheria and, more recently, pneumonia and streptococcic infections. The reduction of these infectious diseases has permitted people to live to the age when hypertension and arteriosclerosis take their greatest toll. No strict proof exists that the blood vessel diseases are increasing for any other reason than the population's increasing age. I say "no strict proof" advisedly, for it is possible that the faster tempo and increasing frustrations of contemporary living may indeed foreshadow a greater incidence of hypertension independent of age.

Before discussing what hypertension is, it is essential to make clear that the various blood vessel and heart diseases are all parts of a closely interrelated complex, although many people, including many physicians, think of them as separate entities. Actually high blood pressure is very often the cause of hardening of the arteries, and arteriosclerosis in turn may lead to any one of three types of overt breakdown, depending on the vital area that it damages: 1) apoplexy, or stroke in the brain; 2) coronary thrombosis, or circulatory obstruction and failure of the heart; and 3) failure of the kidneys with resultant uremia. Broadly speaking, all of these conditions must be grouped together as "cardio-vascular-renal" (meaning heart-blood vessel-kidney) diseases, but their connection is generally overlooked. Thus apoplexy is often listed as the cause of death, although the underlying disease which caused the apoplexy may be hypertension or arteriosclerosis or both. Similarly, "failure of the heart" or "failure of the kidneys" may be but a manifestation of the real cause—the destructive effects of abnormally high blood pressure. In other words, a large proportion, perhaps a majority, of failures of the vital circulation of the heart and other organs derives from high blood pressure and hardening of the arteries as the basic causes.



CAPILLARIES, magnified 160 diameters through the skin at the base of the fingernail, form fine loops.

Blood pressure in the human body is regulated by an extraordinarily complex and sensitive mechanism. Blood pumped from the heart flows through ever-narrowing channels (arteries and arterioles) into the smallest blood vessels—the capillaries. Great pressure is needed to pump the blood through the arterial system. But to avoid injury to the delicate capillary bed, the function of which is to provide for the chemical needs of tissue cells, the pressure must be sharply reduced. This job is performed by the small, muscular arterioles, which strongly resist blood flow and, like a series of dam gates, reduce the flow into the capillaries to a gentle trickle. The channels that lead from the capillaries back to the heart broaden as they join and form veins. Little pressure is required to lead blood back to the heart. "Blood pressure," as conventionally measured, is taken as the level of pressure in the larger arteries.

WHEN modern methods of measurement came into use some 45 years ago, arterial pressure in normal adults was found to average 120 millimeters of mercury at the height of the ejection of blood from the heart and about 70 mm. of mercury in the interval between beats. The former is called the systolic and the later the diastolic pressure, and the two are recorded as 120/70 mm. Hg (mercury's chemical symbol).

It is important to remember that perfectly normal people may show wide variations from this average. But establishment of normal values led to the observation that arterial pressure in some people is persistently and abnormally increased. This condition is called arterial hypertension. Any value persistently above 150/90 mm. Hg may be considered abnormal. In some patients the pressure may be as high as 260 to 300 mm. Hg systolic and 140 to 170 mm. Hg diastolic, but the average for well-established hypertension is 220/126 mm. Hg.

Except in a very general way, the height of the blood pressure is not a direct measure of the severity of the disease nor of the outlook for the patient. The outlook is

often far more dependent on the quality of blood vessels with which the patient is born, for it is the wear and tear on blood vessels that usually causes death of the patient. Thus the blood pressure reading alone, without other measurements of the condition of the blood vessels and heart, is an unreliable guide.

Since many things may cause persistently high blood pressure, it is necessary to inquire with great care into the origin and the mechanism of the elevation in each case. It is found that some cases are due to disease of the kidneys, such as Bright's disease; some to disease of the adrenal glands, such as tumors; some to diseases of the brain, and so on. But most are due to a cause that is still unidentified. It is this multiplicity of causes and mechanisms which makes for widely different prognoses in individual patients.

The arterioles of patients who have long suffered from arterial hypertension are often thickened, narrowed and fibrous. Some physicians early took the view that this hardening, or sclerosis, was the cause of the increased pressure. They reasoned that the thickening of the vessels impeded the flow of blood, which in turn forced the body to raise arterial pressure lest the tissues receive insufficient blood to nourish them. But other investigators have come to the conclusion that the hardening of arterioles is not the cause but the result of increased arterial pressure. The two diametrically opposed views have resulted in differing approaches to the study of the disease, to treatment and to estimation of the outlook for the patient.

Hardening of the arterioles is believed to be largely irreversible; and so it is, as our present remedies go. The early belief that damage to the blood vessels preceded the rise in blood pressure had gloomy implications, for it suggested that there was little to do but tell the patient that the damage was done, that it would inexorably increase, and, for want of anything better to say, that he had better take it easy.

But the bulk of evidence is now in favor of the second view: that vessel damage is due to the strain of increased pressure. It appears that the beginning of the process is a contraction of the muscles of the arterioles, which narrows the vessels so that the heart must beat harder and pressure must rise to maintain the circulation. This explanation unfortunately does not indicate the basic cause of the contractions. For lack of a better name, the process is called "essential hypertension," meaning that the first abnormality that is discovered is the increase in arterial pressure. Nonetheless this newer view, now well established, is a great deal more heartening than its predecessor, for the contraction of muscles, unlike their hardening, is at least theoretically reversible. It endows the problem of dealing with arterial hypertension with two specific objectives, the first being the removal of the causes of increased pressure and the other the arrest and prevention of vessel damage.

The chain of damaging events proceeds in this wise: The increased force of the heartbeat, in combination with the narrowing of the arterial tree, leads to elevation of the blood pressure. The increase in the power of the heartbeat is accomplished only by dint of increased work. This in turn leads to enlargement of the heart muscle, just as any muscle increases in size when persistently given more work to do. But the time must come when the heart can no longer keep up with the demand made on it, and it fails. Even before that, elevated blood pressure may have done widespread and various damage. If the blood vessels are unable to withstand the increased pressure, they rupture. If they rupture in the brain, a stroke results. Sometimes the blood vessels in the kidneys fail, and uremia results. The kidneys are peculiarly vulnerable because they are composed in large part of blood vessels.

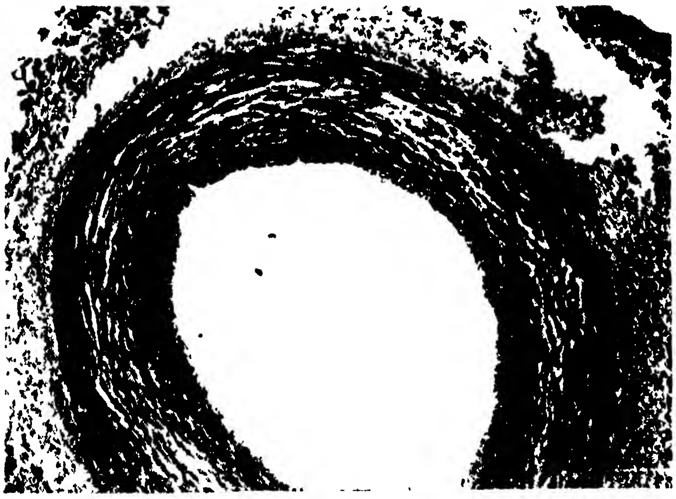
Hypertension can be produced in animals by changing the character of the pulsing stream of blood to the kidneys. Is some similar mechanism at work in the kidneys of man? As yet there is no proof that this is so, but it has provided an important approach for investigation of the problem of the origin of hypertension.

In animals, hypertension may be artificially caused by one of two methods. The first consists of constricting the main artery to the kidneys by means of an adjustable clamp. The second is to envelop the kidneys in a sheet of cellophane or silk. The foreign material acts as a strong irritant, and, in the attempt to wall off the irritation, the body grows a stiff hull around the kidneys which holds them firmly and prevents their normal pulsation. When this occurs, the blood pressure rises.

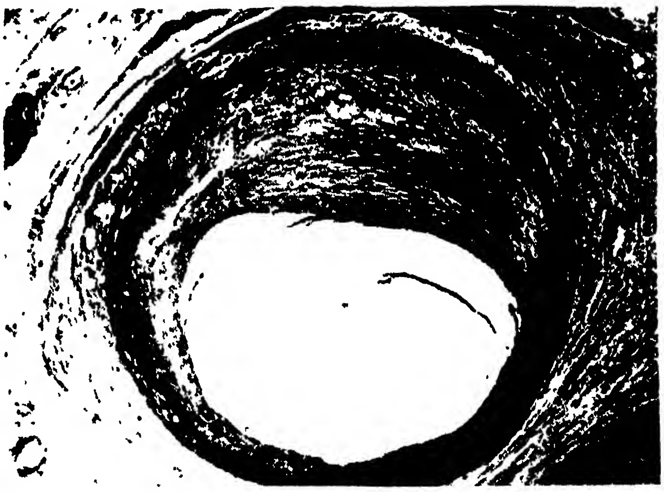
From work on animals with experimental hypertension of kidney origin has come the view that an enzyme called renin, which is contained within the kidney, is liberated into the blood stream. It acts on a protein in the blood to produce a substance called angiotonin, or something very much like it. This angiotonin-like substance seems to be the villain that raises blood pressure. Probably the most important evidence in favor of this view is that the physiological mechanism which seems to operate in the experimental elevation of blood pressure is almost identical with that in patients having essential hypertension.

THE FORMATION of angiotonin is a matter of much interest. It is the first example in which an enzyme seems to be acting as an internal secretion. Possibly other internal secretions will prove to have similar mechanisms. Since the protein on which renin from the kidneys acts is produced by the liver, it is easy to see that the bodily mechanisms for the control of blood pressure are widespread, involving many organs and substances.

The chemical mechanisms which control the expansion and contraction of blood vessels and the amount of blood



HEALTHY ARTERIOLE, magnified 50 times, has a cross section of even, muscular walls. Contraction of muscles regulates blood pressure in the capillaries.



SCLEROTIC ARTERIOLE has hardened and fibrous walls. Progressive sclerosis of the walls narrows the channel for blood flow and contributes to high pressure.

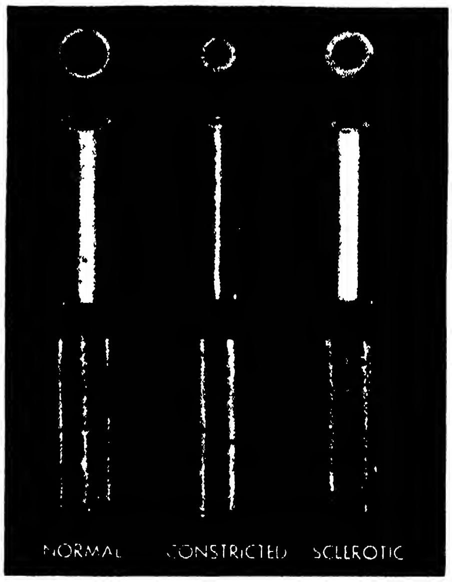
flowing to tissue are exceedingly complex; naturally so. since they have a complex job to do. Each new discovery of a substance which either raises or lowers blood pressure tends to overemphasize the actual importance of that substance, and to lead to disappointment. Thus at one time adrenalin, the internal secretion of the inner portion of the adrenal glands, was believed to be the cause of hypertension. When it was found that this was not true, a nihilistic wave set in which all but left adrenalin without function in the body. Only recently has a truer light been shed on its function.

As an illustration of the complex interplay of the pressure-elevating substances, consider the effect of feeding meat or salt to animals which are given injections of one of the hormones of the adrenal cortex. If salt in particular is withdrawn from the diet, the hormone does not raise blood pressure and seems to produce little injury to the blood vessels. But feed a bit more than the usual amount of salt and the injections now cause a marked rise in blood pressure and severe injury to the blood vessels. It would be easy to assume, of course, that the same is true of patients with hypertension, and to draw the conclusion that salt or meat is the cause of hypertension. There is just enough truth in this view to make it tantalizing. A very low salt diet lowers blood pressure in some patients, but by no means in all. Furthermore, no one has yet proved that the adrenal hormone employed experimentally in animals is present in human adrenal glands, except in minute amounts. Clearly there is much that is highly suggestive in these observations, but the kernel of the problem has not been reached.

Some years ago the research group with which I have been associated was treated to an amusing demonstration of how easy it is to be misled in this field of investigation. We observed that a substance extracted from the urine of supposedly normal physicians working in the hospital greatly raised blood pressure when injected into animals. But this substance could not be found in the urine of our hypertensive patients. An interesting possibility at once suggested itself: the substance might be a blood pressure-elevating agent which normal people got rid of in the urine but which the patients retained. Their inability to get rid of it might be the cause of their high blood pressure. The substance was carefully isolated, crystallized and identified. It turned out to be pure nicotine! The patients had been kept figuratively under lock and key by a strict head nurse who did not believe in the virtue of the minor vices. Smoking was banned for the patients, but not for the physicians. So the mystery was solved, but little was added to knowledge of essential hypertension. There was, however, one incidental addition to our general information. Up to that time, it had been generally believed that nicotine was largely destroyed by the liver; our observation showed clearly that much of it is eliminated in the urine.

RECENTLY an interesting substance has been found in the blood of animals when they are in shock or after crude extracts of kidneys have been injected into their bloodstream. When the substance is injected into normal animals, it produces only a transient rise in blood pressure. But if the kidneys of the animal have been removed a day or two before, then the blood pressure rises greatly and stays elevated for several hours. The substance seems to have its origin in the kidneys and its effect seems to be controlled by the presence of kidneys. But is it concerned in the mechanism of the elevation of blood pressure in man? No one yet knows the answer, but all would admit the challenge of the problem.

A substance such as angiotonin must have blood vessels to act on to produce hypertension. The vessels' response is normally controlled by a variety of factors, among them being the endocrine glands, the liver and the nervous system. The interplay of these various factors influences to a great extent the height of the blood pressure when the organism is acted on by angiotonin. The precise unraveling of the complicated skein is one of the urgent medical problems now being investigated. It would seem reasonable to suppose that as the degree of participation by the various organs in the mechanism elevating blood pressure becomes measurable, a much broader range of methods will be found to modify the level of the arterial pressure.



DIAMETERS of healthy and sclerotic blood vessels show root of hypertension and arteriosclerosis. Constant constriction often leads to sclerosis.

A great deal of evidence derived from bedside examination of patients suggests further that the kidneys play an important part in hypertension. For example, elevation of arterial pressure is the common accompaniment of Bright's disease and pyelonephritis, both diseases of the kidneys. Presumably the kidneys in such cases initiate the rise in blood pressure. But most patients with essential hypertension do not begin with manifest kidney disease. It is believed by many that heightened activity of the nervous system caused by repeated narrowing of the vessels of the kidneys is the trigger that starts the liberation of substances that elevate blood pressure. Indeed, Josep Trueta of London has suggested that nervous stimulation shunts blood away from the cortex of the kidneys, leaving it bloodless, and that this bloodlessness sets in motion reactions, otherwise not occurring, which produce blood pressure-elevating substances. But there seems to be little evidence to support such a concept of the origin of essential hypertension.

The impression should not be created that the kidney theories are the only views currently held by investigators of the origin of hypertension. They are perhaps the most commonly held. Others believe that essential hypertension begins as a result of stress and strain acting on the pituitary gland. They suggest that the pituitary acts on the adrenal glands to stimulate the excretion into the blood stream of a substance noxious to the blood vessels of the kidneys, thus initiating a chain of events which culminates in the appearance of a chemical substance like angiotonin in the blood. This substance in turn is responsible for the narrowing of the arteriolar bed and the stimulation of the force of the heart beat which eventuates in persistent hypertension.

Some believe that hypertension is of purely nervous origin, that the "set" of the mechanism in the brain which regulates blood pressure is altered in an upward direction to cause hypertension.

There is great interest among physicians at present in the view that hypertension is a disease of psychogenic origin, or one of failure of the mechanism of adaptation to respond properly to the unfavorable environment in which most men find themselves. So far no proof has been found that emotional factors are ever the direct cause of essential hypertension. But the fact that hypertensive people commonly show unusual emotional patterns suggests a close if not causal relationship. One thing is certain: the acquisition of equanimity is usually associated with a marked reduction of the level of blood pressure and betterment of the patient's condition. As Plato observed more than 2,000 years ago: "He who is of a calm and happy nature will hardly feel the pressure of age."

Whether there is such a thing as a hypertensive personality in whom hypertension almost inevitably develops seems doubtful. Certainly the layman's picture of the hypertensive as an overactive, ebul-

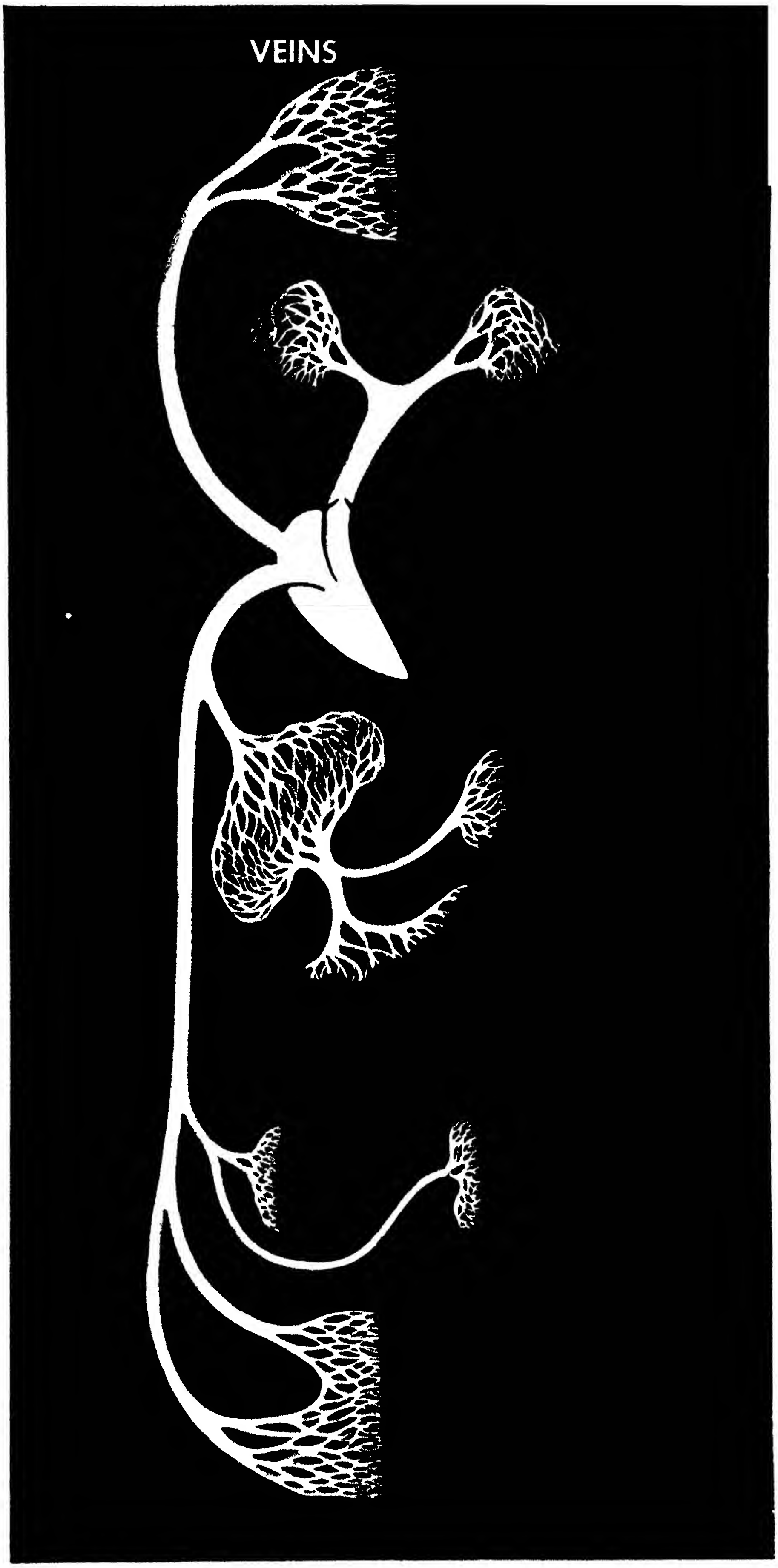
lient, expansive, aggressive individual is not correct. Most observers agree on only a few common characteristics: emotional instability, anxiety and resentment often associated with failure to achieve a lofty ambition. Since many hypertensive people have emotional problems, proper care of them always includes intelligent education and guidance, and, in a few, more penetrating psychotherapy such as psychoanalysis.

There is no specific treatment for hypertension, but there are many treatments which can greatly reduce blood pressure and prolong life. Partial or even complete removal of the sympathetic nervous system has been a useful treatment in some patients. Drugs such as potassium thiocyanate are valuable when properly used in the control of intractable headache, and they lower blood pressure as well in some patients. Dihydroergocornine is currently under study and seems to be useful in a limited group of patients. Low salt diets, rice and fruit juice diets are now being actively investigated with, so far, encouraging results. They must be considered, however, as no more than clinical experiments and not established cures.

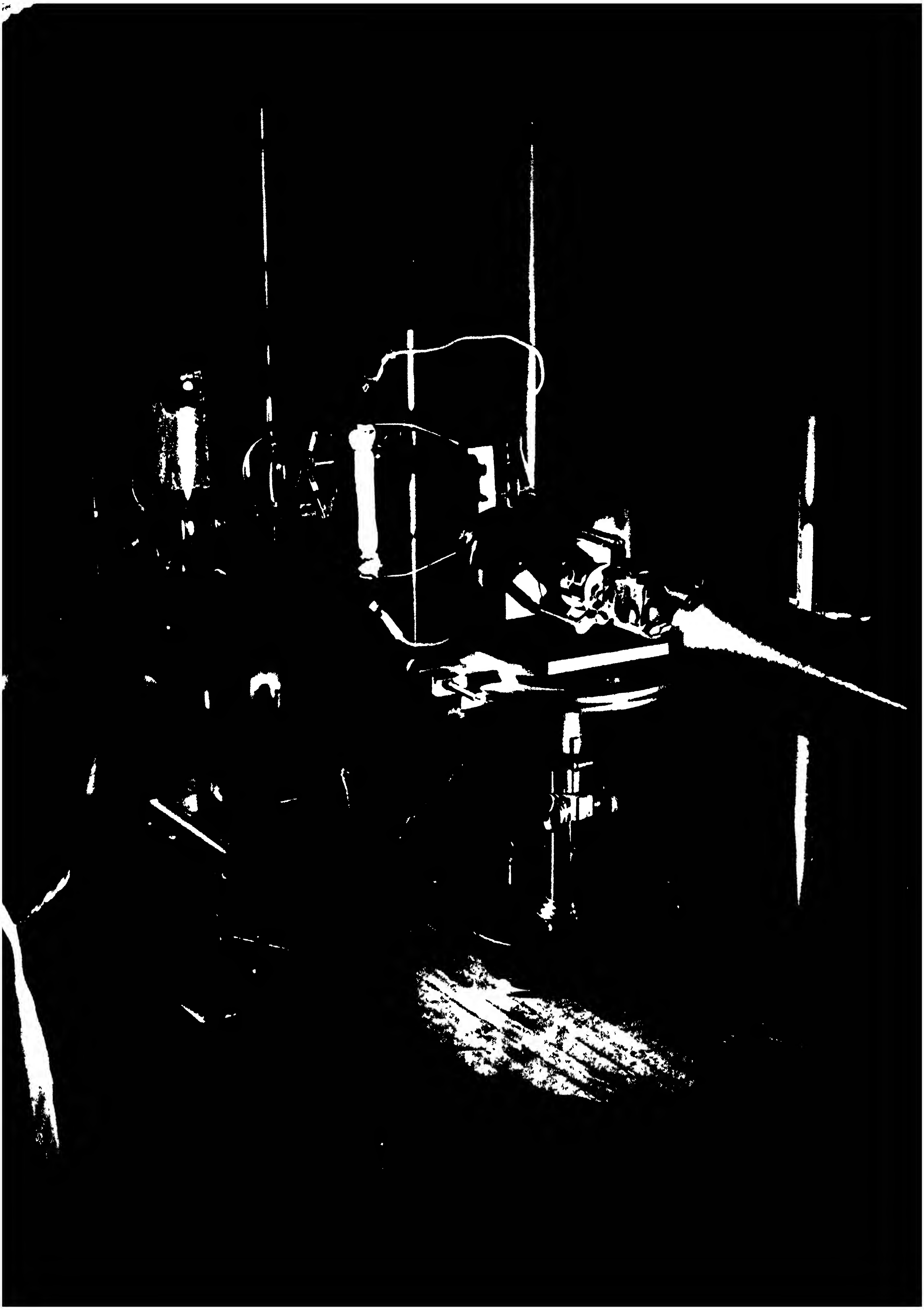
MUCH HAS been made recently of the possibility that hypertension and vascular disease may be caused by an improper adaptation to the frustrations and stresses of civilization. It has been noted that Chinese peasants seem to be relatively free of this disorder. Many years ago George Crile called hypertension a disease of civilization. This view has much to support it, though the final objective proof has yet to be produced. Hans Selye of Toronto has done much to crystallize research which may well lead to an understanding of the way in which the nervous system participates in the genesis and maintenance of high blood pressure. If hypertension and arteriosclerosis are the price we must pay for being civilized, we must find cures for them, or determine what part of civilization exacts such a price. We cannot and will not give up civilization.

The hypertension problem is in a healthy competitive state among its investigators. Further, it has begun at long last to fire the imagination of young researchers and intelligent laymen. The weight of ancient authority is dropping away and in its place critical investigation is appearing, much of it of very high caliber. With continued or, one hopes, much accelerated research, the outlook should be much improved within a relatively short time. Hypertension is a disease which man should be able to conquer. In doing so, he will rid himself of his most lethal enemy.

Irvine H. Page is director of the research division at the Cleveland Clinic and author of medical works.



THE CIRCULATORY SYSTEM and its various organs are outlined in this much simplified diagram. The fine networks of capillaries at the top and bottom represent all those which carry blood to the body's multifarious cells. The branches between the arteries and capillaries are the muscular arterioles.



MEASUREMENT BY MERCURY

The length of a light wave has been our most accurate yardstick. Now the light of a rare isotope transmuted artificially from gold provides the ultimate standard

by William F. Meggers

HOW LONG is an inch? As long as the end joint of a man's index finger, in common lore. The schoolboy and the carpenter define it somewhat more precisely as the distance between two lines on a common wooden ruler. That will do for rough measurement, but we are still far from an exact definition. Rulers are not uniform; they are subject to swelling and shrinking; the coarse lines with which they are marked add a further margin for error. In a fine-structured civilization whose tolerances are measured in millionths of an inch, obviously the inch must be more accurately defined. We need an inch (or a more cosmopolitan measure, the meter, from which the inch may be derived) that is the same everywhere on earth, that remains invariable regardless of time, temperature or other circumstances, and that can be reproduced at will from some fixed, universal standard.

Let us take the most inflexible of metals, cast it in the shape of an end-gauge or calipers and calibrate it to the exact dimensions of our unit. Very good, but our problem has only just begun. Where shall we find the ultimate measure upon which to gauge our instrument? We arrive, finally, at the International Bureau of Weights and Measures near Paris. There in a guarded vault lies a platinum-iridium bar. On it are two fine ruled lines, six to eight microns wide and a certain distance apart. By world agreement, the distance between the centers of the two lines is exactly one meter when the bar is at the temperature of melting ice.

WAVELENGTHS of various spectral lines of mercury 198 are measured by comparing them in the Bureau of Standards laboratory with the lines of cadmium, the best previous standard. Mercury light, produced by the lamp at the left, is made to produce interference fringes by interferometer in right center. Cadmium light, produced by lamp in left center, also passes through interferometer. Fringes are separated by prism (*out of picture to the right*) and compared. Here a small prism has been placed behind interferometer so observer Meggers can make adjustments needed to produce fringes.

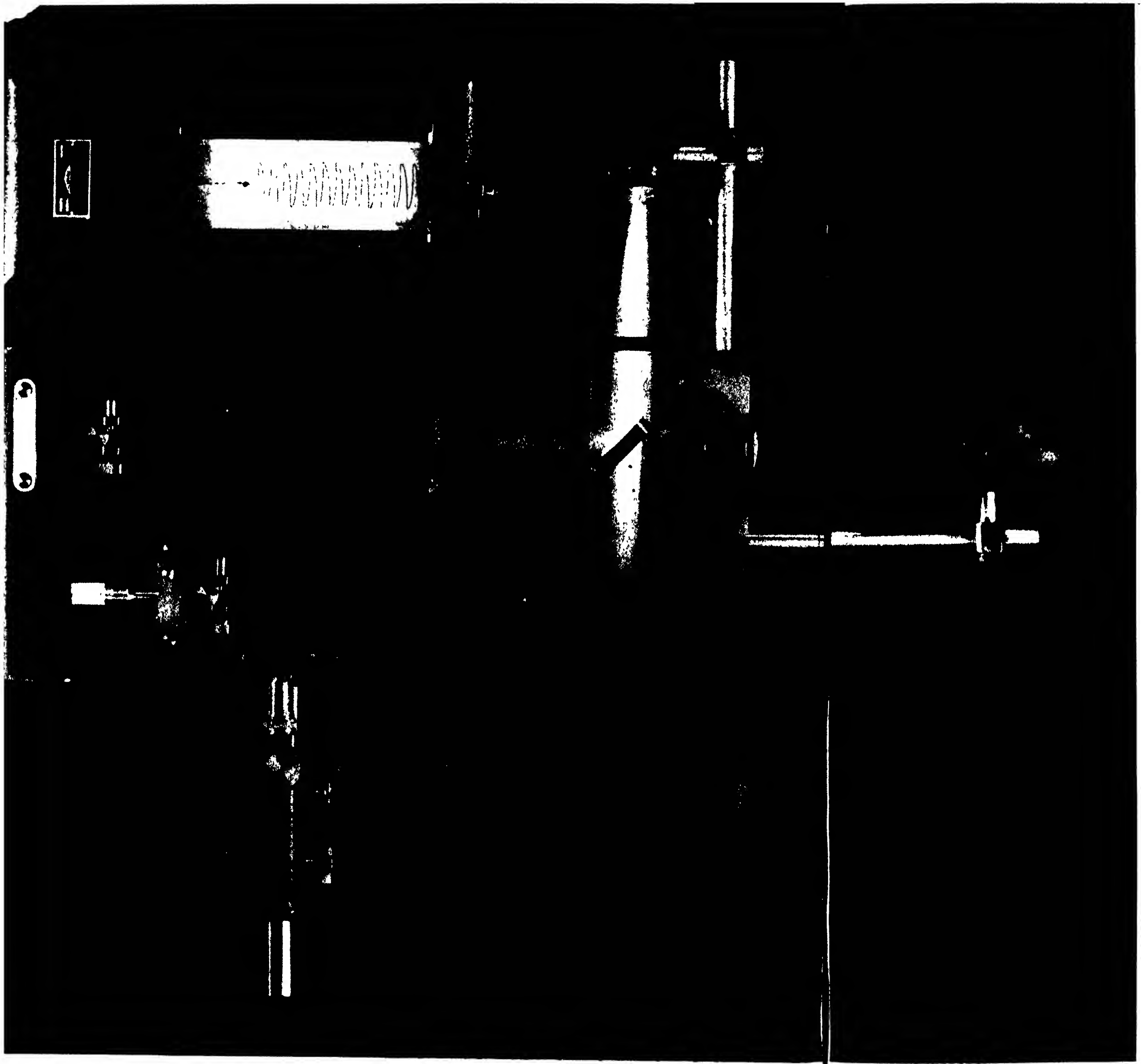
That bar near Paris has been a constant worry to the world. The meter, as everyone interested in scientific measurement knows, was designed in the 1790s to represent one ten-millionth of the earth's quadrant (the distance from the North Pole to the Equator). As early as 1827, a group of natural philosophers meeting in Paris was struck by a disquieting thought: Suppose a comet collided with the earth and changed its size or shape. The standard meter, on which all earthly measurements depended, could not be reproduced from its definition. Before the century's end, earth surveys of greater accuracy showed that the original meter was not exactly one ten-millionth of the quadrant but was one part in 5,000 too short. So in 1889 the meter's definition in terms of the earth was abandoned and it was arbitrarily defined as a certain distance on the platinum-iridium bar almost identical with the original prototype meter. Since then the world's standard of measurement has depended on that frail piece of metal, which has remained the master standard though copies have been distributed to other countries. During World War I there was great fear that a bomb might destroy the master bar. Many scientists agreed that a new standard was urgently required.

Sir Humphry Davy, the 17th and 18th century chemist-poet, had been the first to propose such a change. He suggested as a natural standard of length the diameter of a capillary tube of glass in which water would rise by surface tension to a height exactly equal to the tube's diameter. Jacques Babinet, a French natural philosopher, suggested that a wavelength of light in a vacuum would be a better one. In 1887, the American physicists A. A. Michelson and E. W. Morley translated this suggestion into a practical method. They showed how to measure length by means of the instrument called the interferometer, which they had devised for their celebrated experiments on the motion of the earth through the "ether."

The interferometer is an essentially simple instrument designed to make waves of light overlap and interfere with one another. The simplest interferometer, known as the Fabry-Perot type, consists of two optically flat glass or quartz plates separated by a certain distance and adjusted accurately parallel to each other. The sides of the plates that face each other are coated with thin films of silver or other metal to reflect most of the light but to let part of it through. When a beam of monochromatic light is directed through the instrument, the light that filters through the first plate is trapped between the two plates and begins to bounce back and forth. With each bounce, some light passes on through the second plate to a viewing apparatus. The waves that bounce back combine with following waves. At the viewing end the combined waves form a series of concentric "interference fringes," each fringe representing a wavelength. Bright rings occur where the waves reinforce each other and dark ones where they cancel each other.

THE DIFFERENCE between the diameters of the fringes depends on the double distance (to and fro) between the two interferometer plates, in other words, on the length of each bounce. By varying the distance between the plates, one may alter the pattern of fringes. When the center of the pattern shows maximum brightness, it means that the number of light waves in the double distance between the plates is a whole number, because the successive components are all in phase to interfere constructively. If the center is dark, it means that the number of waves is an integer plus a fraction; at maximum darkness this fraction is ½, that is, the waves are ½ wavelength out of phase and the crest of one wave coincides with the trough of another.

Here, then, is a means of establishing an absolute, invariable standard of length. It rests upon a wavelength of light—an immutable constant of nature under reproducible conditions. Count the first circular fringes, determine the extent to which the waves are out of phase at the center of the circle, and the result is the number of waves, plus the fraction of a wave, that spans the double distance between the two plates. From the known wavelength of the light that is used, it is easy to compute the exact distance between the plates. With monochromatic waves the fraction representing the distance by which the waves are out of phase can be determined to 1/1,000 of a wave-



length, and therein lies the unique advantage of measuring lengths with light waves: we are using a scale division 10,000 times finer than the lines ruled on a meter bar.

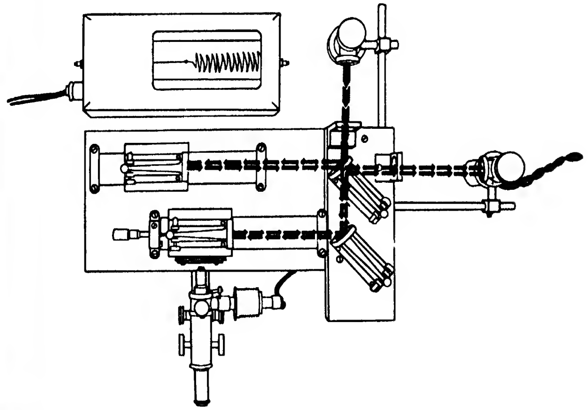
But the problem is less simple than Michelson and Morley at first supposed. We cannot use just any wavelength of light. To attain real accuracy we must employ a homogeneous or monochromatic wave that gives a single sharp spectral line. A complex light source produces fringes that are much too fuzzy. Sixty years ago it was generally assumed that all spectral lines were monochromatic and invariable. Michelson and Morley began by using the wavelength of yellow light emitted by sodium; then they shifted to the green light of mercury, which they suggested would in all probability prove to be the best ultimate standard. Michelson soon discovered, however, that atomic radiations in general were far from monochromatic; the light from each element was made up of a multiplicity of components (now known to be due to the varying nuclear spin of atoms and to the mixture of isotopes that make up almost every natural element). In particular, he found that the green mercury line was one of the most complex in nature. He therefore settled upon the red light of cadmium, which was the most nearly monochromatic among the elements that he studied.

THE NEXT STEP obviously was to measure the cadmium wavelength against the platinum-iridium meter bar. In 1892 Michelson went to the International Bureau of Weights and Measures and made the first such measurement. This experiment has been repeated eight times since then. The average value obtained for the cadmium red wavelength from these nine measurements is 6438.4696 angstroms (one angstrom=1/100,000,000 cm.). The deviations are within the limits of accuracy of the measurements, which would seem to indicate that in half a century the meter bar has changed amazingly little if at all. Yet metal end-gauges, with which it is possible to measure wavelengths more accurately than with a ruled bar, have been found generally to change with time, so there is no *a priori* reason to believe that the international meter bar is strictly immutable. A wavelength of monochromatic light, on the other hand, can reasonably be assumed to be of unchanging length under standard conditions.

Yet the red line of cadmium is a relatively crude measure. It lacks the sharpness required for maximum accuracy. And the counting of fringes demanded by Michelson's method is a labor of fantastic tediousness; there are 1,553,164 red cadmium wavelengths or fringes in a meter!

Since 1931 research has been focused anew on the green line of mercury, which Michelson once considered and rejected. And now at long last we have found the answer in an artificial isotope of mercury obtained by transmuting gold—a reversal of the alchemist's age-old goal. This isotope, Hg^{198}, emits a sharp green line free from complex structure. This wavelength is not only the best standard that has been found but the best that can be found. In mercury 198 we have finally discovered the ultimate standard of length.

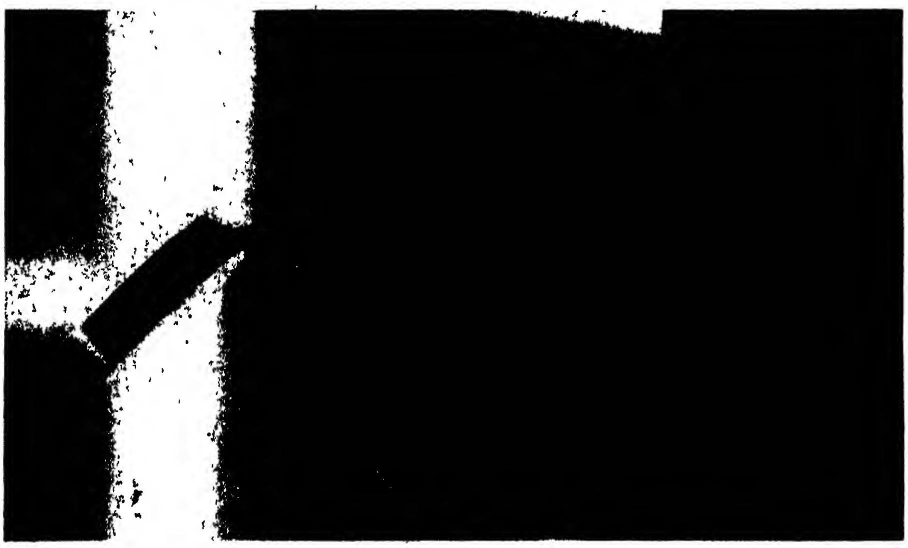
Natural mercury consists of a mixture of seven isotopes with the mass numbers 196, 198, 199, 200, 201, 202 and 204 (relative to oxygen 16). Green light from natural mercury consists of 16 components ranging over half an angstrom, that is, more than 100 times the width of a single component. Since isotopes of even mass number have no detectable nuclear spin (one factor which complicates the struc-



HOW INTERFEROMETER can translate the length of light waves into units of practical size is shown in this demonstration prepared by the Bausch and Lomb Optical Company. The interferometer here is not the type used in measuring the wavelength of light from mercury 198, nor has mercury 198 been used in this kind of measurement. The demonstration is nonetheless a remarkably clear exposition of the interferometer and its use. As clarified in the diagram at the right, light from the lamp at the top of the photograph is split into two beams by a half-silvered mirror in center. The two beams, bouncing back from the two mirrors at left, then unite before entering photocell at right. When the lower of these two mirrors is moved by fine screw adjustment at left, light waves in the two beams are set out of phase to produce circular interference fringes. When the mirror is moved farther, the fringes pass across aperture of photocell and are recorded by device at upper left. Observer at microscope below can then relate the number of fringes to marked scale on movable mirror carriage.

ture of spectral lines), the problem was to isolate an even-numbered isotope that would emit a single, distinct line. Mercury 198, which does not exist in a pure state in nature, was first obtained from gold in 1934 by Enrico Fermi and others. When gold (Au^{197}) is bombarded with neutrons, it yields a radioactive isotope of gold that decays rapidly and becomes stable Hg^{198}. In 1940 Luis W. Alvarez of the University of California demonstrated that neutron bombardment from a cyclotron transmuted sufficient gold into mercury to be detected with a spectroscope. The National Bureau of Standards thereupon purchased 40 ounces of proof gold and requested the University of California to bombard it with neutrons for one or more years. World War II interfered with this project, but near the end of the war there

mium in the interferometer—a method 10 times more accurate than measuring it from the meter bar. Comparison of wavelengths in an interferometer is one of the most beautiful experiments in physical optics; in simplicity and precision it is outstanding among physical measurements. Light from mercury 198 and from cadmium is beamed simultaneously into the interferometer. At the viewing end their interference patterns are shown not as circular fringes but, by projection through a prism and lens, as slit images of diametral sections of fringes without overlapping. The green wavelength of Hg^{198} is easily computed from the red wavelength of cadmium by a method that depends on a comparison of the number of waves of the respective emissions in the double distance between the plates. The green



CLOSEUP of interferometer on pages 50 and 51 shows initial beam at top being split in two by half-silvered mirror. Beam returning from the left then passes through mirror. Beam returning from bottom is reflected from mirror back. Picture shows top view of fringes similar to those on opposite page.

arose rumors of a secret source of neutrons thousands of times more effective than the largest cyclotron. In 1945 the Bureau of Standards gold was transferred to an atomic pile at Oak Ridge, and there, within a year, was produced more than 60 milligrams of highly pure mercury 198.

With this mercury several lamps were made, each using about five milligrams. The simplest is a sealed glass vacuum tube of the size of a cigarette, in which mercury vapor is excited to emit light by high-frequency radio waves. By this method intense light emission can be obtained at extremely low vapor density and temperature, which are necessary conditions for sharp lines. It was at once found that the green light from Hg^{198} produced incomparably sharper fringes than natural mercury.

To use the Hg^{198} fringes for length measurements, the wavelength of the light itself had to be accurately measured. This was done by comparing the Hg^{198} wavelength with that of the red light of cad-

wavelength of Hg^{198} was thus determined to be 5460.752 angstroms, or about 21.5 millionths of an inch. It can be measured by this method with an accuracy of one part in 100 million. And theoretically any length of 10 inches or more can be measured by Hg^{198} and an interferometer with this accuracy.

But how can one be sure that mercury 198 is the *ultimate* standard? The reasons are clear and conclusive. The green line of Hg^{198}, the brightest in mercury's spectrum, coincides almost exactly with the wavelength to which the human eye is most sensitive; it is, for example, 70 times as intense to the eye as the red line of cadmium—a great advantage for the visual adjustment of an interferometer. The weight of mercury is an additional advantage. At low pressures and moderate electrical excitation the monochromaticity of atomic radiations varies as the square root of the atomic mass divided by the absolute temperature. The random motions of radiating particles tend to make spectral lines fuzzy. Naturally these atomic motions are least for heavy particles at low temperatures. Since mercury atoms are nearly twice as heavy as cadmium atoms and radiate strongly at less than half the absolute temperature, mercury waves will be less than half as fuzzy as cadmium waves, other things being equal.

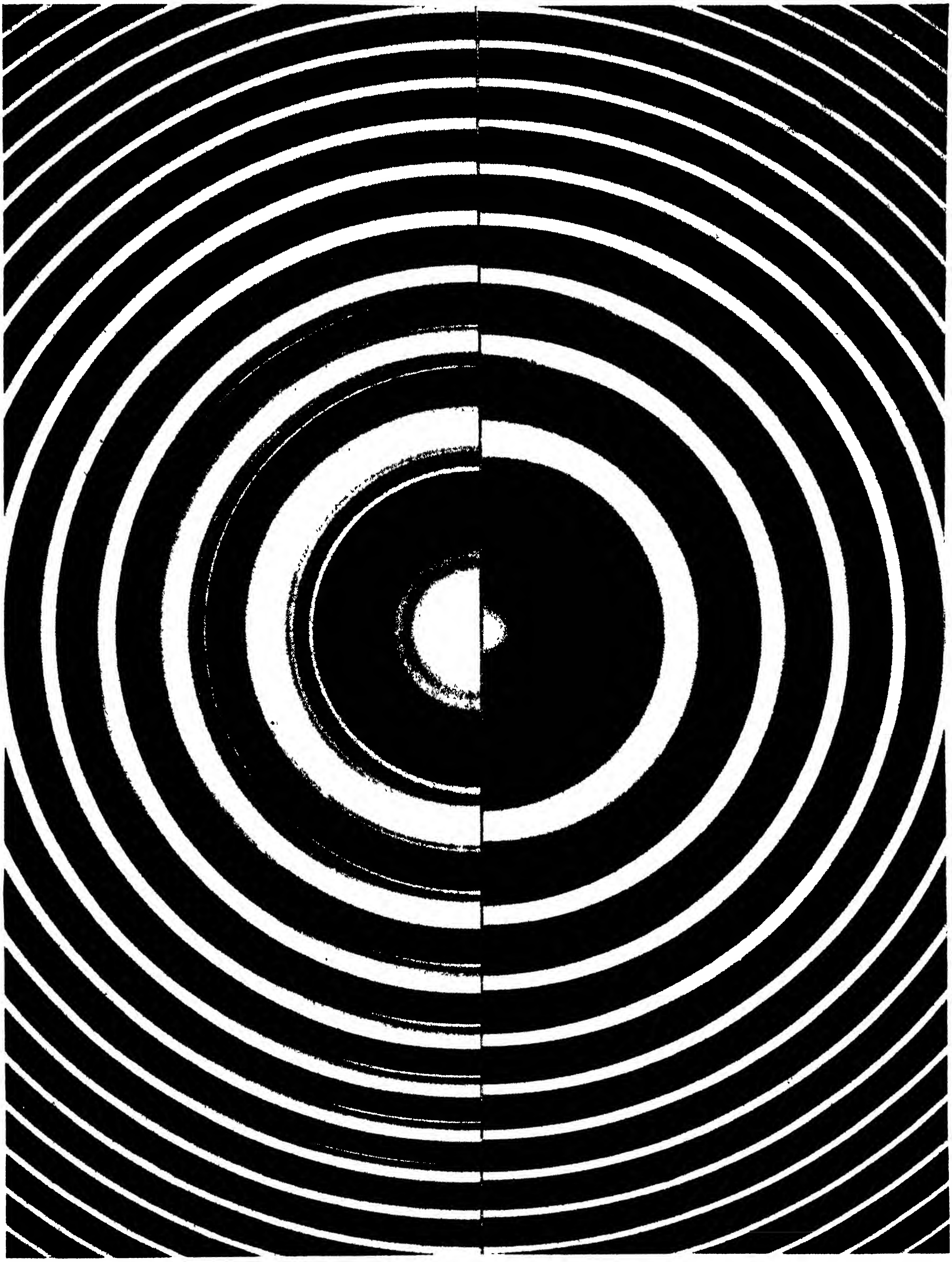
Moreover, to obtain enough cadmium vapor to produce a spectrum, the element must be heated to between 300 and 320 degrees C. This high temperature adds fuzziness to the waves. Mercury, in contrast, has sufficient vapor pressure even at its freezing point (−39 degrees C.) to yield a spectrum through excitation by a high-frequency electric field. Indeed, mercury is unique among all elements in radiating, at low pressure and temperature, a relatively simple spectrum of intense and exceedingly sharp lines, provided that its isotopic structure is eliminated. Furthermore, mercury has another extremely convenient property: by the use of a pair of yellow mercury lines that produces interference coincidences at intervals of 275 waves, the order of interference in the interferometer can be determined without counting the fringes.

THUS THE GREEN line of mercury now stands alone as the most nearly ideal standard wavelength that can ever be obtained from any atoms, natural or artificial. Its unique properties force the conclusion that a progressive scientific world will soon adopt the wavelength of green radiation from Hg^{198} (5461 angstroms) as the ultimate standard of length.

The writer wishes to emphasize that he is not trying to abolish the meter or the metric system. On the contrary, he is anxious to perpetuate both by giving the meter a scientific definition that will make it more accurately reproducible. The meter is here to stay. It remains a very convenient and useful instrument for calibrating ruled scales, with which most length measurements are made. Nonetheless, it is highly arbitrary and unscientific to define the primary standard of length as a distance between two relatively coarse, irregular lines on a metal-alloy bar.

Light waves as a measuring tool can be produced any time, anywhere. They have set new standards of accuracy in measurement. The last possible improvements in this direction can now be made by recognizing the Hg^{198} wavelength as the ultimate standard and by perpetuating a constant and more accurately reproducible meter through its definition in terms of that standard.

William F. Meggers is chief of the spectroscopy section of the National Bureau of Standards.



INTERFERENCE FRINGES produced by the green light of natural mercury (*left half of picture*) and of mercury 198 (*right half*) are compared to show the fundamental advantage of the latter. The fringes of natural mercury are broad and complex. Fringes of mercury 198 are narrow and sharp. Sharper fringes of mercury 198 make possible more precise interferometric measurement and greater flexibility in interferometer's use.

MATHEMATICAL CREATION

An essay written early in this century by the great mathematician Henri Poincaré is still a remarkable insight into the creative processes of the intellect

Edited by James R. Newman

How is mathematics made? What sort of brain is it that can compose the propositions and systems of mathematics? How do the mental processes of the geometer or algebraist compare with those of the musician, the poet, the painter, the chess player? In mathematical creation which are the key elements? Intuition? An exquisite sense of space and time? The precision of a calculating machine? A powerful memory? Formidable skill in following complex logical sequences? A supreme capacity for concentration?

The essay below, delivered in the first years of this century as a lecture before the Psychological Society in Paris, is the most celebrated of the attempts to describe what goes on in the mathematician's brain. Its author, Henri Poincaré, cousin of Raymond, the politician, was peculiarly fitted to undertake the task. One of the foremost mathematicians of all time, unrivalled as an analyst and mathematical physicist, Poincaré was known also as a brilliantly lucid expositor of the philosophy of science. These writings are of the first importance as professional treatises for scientists and are at the same time accessible, in large part, to the understanding of the thoughtful layman.

THE GENESIS of mathematical creation is a problem which should intensely interest the psychologist. It is the activity in which the human mind seems to take least from the outside world, in which it acts or seems to act only of itself and on itself, so that in studying the procedure of geometric thought we may hope to reach what is most essential in man's mind. . . .

A first fact should surprise us, or rather would surprise us if we were not so used to it. How does it happen there are people who do not understand mathematics? If mathematics invokes only the rules of logic, such as are accepted by all normal minds; if its evidence is based on principles common to all men, and that none could deny without being mad, how does it come about that so many persons are here refractory?

That not every one can invent is nowise mysterious. That not every one can retain a demonstration once learned may also pass. But that not every one can understand mathematical reasoning when explained appears very surprising when we think of it. And yet those who can follow this reasoning only with difficulty are in the majority: that is undeniable, and will surely not be gainsaid by the experience of secondary-school teachers.

And further: how is error possible in mathematics? A sane mind should not be guilty of a logical fallacy, and yet there are very fine minds who do not trip in brief reasoning such as occurs in the ordinary doings of life, and who are incapable of following or repeating without error the mathematical demonstrations which are longer, but which after all are only an accumulation of brief reasonings wholly analogous to those they make so easily. Need we add that mathematicians themselves are not infallible? . . .

As for myself, I must confess, I am absolutely incapable even of adding without mistakes. . . . My memory is not bad, but it would be insufficient to make me a good chess-player. Why then does it not fail me in a difficult piece of mathematical reasoning where most chess-players would lose themselves? Evidently because it is guided by the general march of the reasoning. A mathematical demonstration is not a simple juxtaposition of syllogisms, it is syllogisms *placed in a certain order,* and the order in which these elements are placed is much more important than the elements themselves. If I have the feeling, the intuition, so to speak, of this order, so as to perceive at a glance the reasoning as a whole, I need no longer fear lest I forget one of the elements, for each of them will take its allotted place in the array, and that without any effort of memory on my part.

We know that this feeling, this intuition of mathematical order, that makes us divine hidden harmonies and relations, cannot be possessed by every one. Some will not have either this delicate feeling so difficult to define, or a strength of memory and attention beyond the ordinary, and then they will be absolutely incapable of understanding higher mathematics. Such are the majority. Others will have this feeling only in a slight degree, but they will be gifted with an uncommon memory and a great power of attention. They will learn by heart the details one after another; they can understand mathematics and sometimes make applications, but they cannot create. Others, finally, will possess in a less or greater degree the special intuition referred to, and then not only can they understand mathematics

HENRI POINCARE was born in 1854, the son of a civil servant and meteorologist. During his fruitful professional life he devoted himself to pure mathematics and its application to physics and astronomy. Author of several books in these fields, he is also known for his writings in the philosophy of science. Poincaré died in 1912.

even if their memory is nothing extraordinary, but they may become creators and try to invent with more or less success according as this intuition is more or less developed in them.

IN FACT, what is mathematical creation? It does not consist in making new combinations with mathematical entities already known. Anyone could do that, but the combinations so made would be infinite in number and most of them absolutely without interest. To create consists precisely in not making useless combinations and in making those which are useful and which are only a small minority. Invention is discernment, choice.

It is time to penetrate deeper and to see what goes on in the very soul of the mathematician. For this, I believe, I can do best by recalling memories of my own. But I shall limit myself to telling how I wrote my first memoir on Fuchsian functions. I beg the reader's pardon; I am about to use some technical expressions, but they need not frighten him, for he is not obliged to understand them. I shall say, for example, that I have found the demonstration of such a theorem under such circumstances. This theorem will have a barbarous name, unfamiliar to many, but that is unimportant; what is of interest for the psychologist is not the theorem but the circumstances.

For fifteen days I strove to prove that there could not be any functions like those I have since called Fuchsian functions. I was then very ignorant; every day I seated myself at my work table, stayed an hour or two, tried a great number of combinations and reached no results. One evening, contrary to my custom, I drank black coffee and could not sleep. Ideas rose in crowds; I felt them collide until pairs interlocked, so to speak, making a stable combination. By the next morning I had established the existence of a class of Fuchsian functions, those which come from the hypergeometric series; I had only to write out the results, which took but a few hours.

Then I wanted to represent these functions by the quotient of two series; this idea was perfectly conscious and deliberate, the analogy with elliptic functions guided me. I asked myself what properties these series must have if they existed, and I succeeded without difficulty in forming the series I have called theta-Fuchsian.

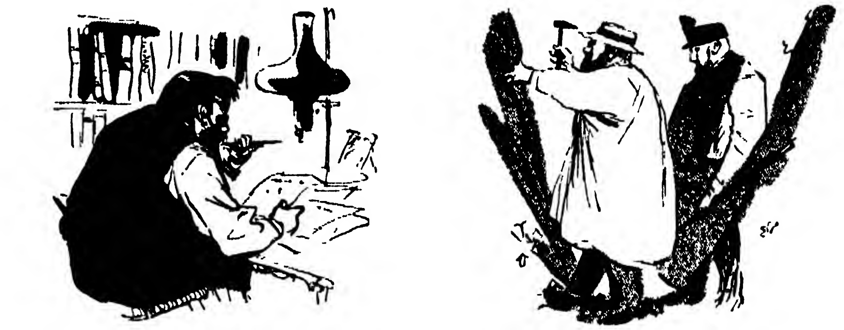
Just at this time I left Caen, where I was then living, to go on a geologic excursion under the auspices of the school of mines. The changes of travel made me forget my mathematical work. Having reached Coutances, we entered an omnibus to go some place or other. At the moment when I put my foot on the step the idea came to me, without anything in my former thoughts seeming to have paved the way for it, that the transformations I had used to define the Fuchsian functions were identical with those of non-Euclidean geometry. I did not verify the idea; I should not have had time, as, upon taking my seat in the omnibus, I went on with a conversation already commenced, but I felt a perfect certainty. On my return to Caen, for conscience' sake I verified the result at my leisure.

THEN I turned my attention to the study of some arithmetical questions apparently without much success and without a suspicion of any connection with my preceding researches. Disgusted with my failure, I went to spend a few days at the seaside, and thought of something else. One morning, walking on the bluff, the idea came to me, with just the same characteristics of brevity, suddenness and immediate certainty that the arithmetic transformations of indeterminate ternary quadratic forms were identical with those of non-Euclidean geometry.

Returned to Caen, I meditated on this result and deduced the consequences. The example of quadratic forms showed me that there were Fuchsian groups other than those corresponding to the hypergeometric series; I saw that I could apply to them the theory of theta-Fuchsian series and that consequently there existed Fuchsian functions other than those from the hypergeometric series, the ones I then knew. Naturally I set myself to form all these functions. I made a systematic attack upon them and carried all the outworks, one after another. There was one, however, that still held out, whose fall would involve that of the whole place. But all my efforts only served at first the better to show me the difficulty, which indeed was something. All this work was perfectly conscious.

Thereupon I left for Mont-Valérien, where I was to go through my military service; so I was very differently occupied. One day, going along the street, the solution of the difficulty which had stopped me suddenly appeared to me. I did not try to go deep into it immediately, and only after my service did I again take up the question. I had all the elements and had only to arrange them and put them together. So I wrote out my final memoir at a single stroke and without difficulty.

I shall limit myself to this single example; it is useless to multiply them....



CREATIVE PROCESS, described by Poincaré, may go on in the subconscious between periods of conscious work. At work on a problem (*first draw-*

Most striking at first is this appearance of sudden illumination, a manifest sign of long, unconscious prior work. The role of this unconscious work in mathematical invention appears to me incontestable, and traces of it would be found in other cases where it is less evident. Often when one works at a hard question, nothing good is accomplished at the first attack. Then one takes a rest, longer or shorter, and sits down anew to the work. During the first half-hour, as before, nothing is found, and then all of a sudden the decisive idea presents itself to the mind....

There is another remark to be made about the conditions of this unconscious work; it is possible, and of a certainty it is only fruitful, if it is on the one hand preceded and on the other hand followed by a period of conscious work. These sudden inspirations (and the examples already cited prove this) never happen except after some days of voluntary effort which has appeared absolutely fruitless and whence nothing good seems to have come, where the way taken seems totally astray. These efforts then have not been as sterile as one thinks; they have set agoing the unconscious machine and without them it would not have moved and would have produced nothing....

Such are the realities; now for the thoughts they force upon us. The unconscious, or, as we say, the subliminal self plays an important role in mathematical creation; this follows from what we have said. But usually the subliminal self is considered as purely automatic. Now we have seen that mathematical work is not simply mechanical, that it could not be done by a machine, however perfect. It is not merely a question of applying rules, of making the most combinations possible according to certain fixed laws. The combinations so obtained would be exceedingly numerous, useless and cumbersome. The true work of the inventor consists in choosing among these combinations so as to eliminate the useless ones or rather to avoid the trouble of making them, and the rules which must guide this choice are extremely fine and delicate. It is almost impossible to state them precisely; they are felt rather than formulated. Under these

ing), Poincaré went on a geology expedition (*second drawing*). The solution came to him as he stepped into omnibus (*third drawing*), was written later.

conditions, how imagine a sieve capable of applying them mechanically?

A first hypothesis now presents itself; the subliminal self is in no way inferior to the conscious self; it is not purely automatic; it is capable of discernment: it has tact, delicacy; it knows how to choose, to divine. What do I say? It knows better how to divine than the conscious self, since it succeeds where that has failed. In a word, is not the subliminal self superior to the conscious self? You recognize the full importance of this question. . . .

Is this affirmative answer forced upon us by the facts I have just given? I confess that, for my part, I should hate to accept it. Reexamine the facts then and see if they are not compatible with another explanation.

It is certain that the combinations which present themselves to the mind in a sort of sudden illumination, after an unconscious working somewhat prolonged, are generally useful and fertile combinations, which seem the result of a first impression. Does it follow that the subliminal self, having divined by a delicate intuition that these combinations would be useful, has formed only these, or has it rather formed many others which were lacking in interest and have remained unconscious?

In this second way of looking at it, all the combinations would be formed in consequence of the automatism of the subliminal self, but only the interesting ones would break into the domain of consciousness. And this is still very mysterious. What is the cause that, among the thousand products of our unconscious activity, some are called to pass the threshold, while others remain below? Is it a simple chance which confers this privilege? Evidently not; among all the stimuli of our senses, for example, only the most intense fix our attention, unless it has been drawn to them by other causes. More generally the privileged unconscious phenomena, those susceptible of becoming conscious, are those which, directly or indirectly, affect most profoundly our emotional sensibility.

It may be surprising to see emotional sensibility invoked *à propos* of mathematical demonstrations which, it would seem, can interest only the intellect. This would be to forget the feeling of mathematical beauty, of the harmony of numbers and forms, of geometric elegance. This is a true esthetic feeling that all real mathematicians know, and surely it belongs to emotional sensibility.

Now, what are the mathematic entities to which we attribute this character of beauty and elegance, and which are capable of developing in us a sort of esthetic emotion? They are those whose elements are harmoniously disposed so that the mind without effort can embrace their totality while realizing the details. This harmony is at once a satisfaction of our esthetic needs and an aid to the mind, sustaining and guiding. And at the same time, in putting under our eyes a well-ordered whole, it makes us foresee a mathematical law. . . . Thus it is this special esthetic sensibility which plays the role of the delicate sieve of which I spoke, and that sufficiently explains why the one lacking it will never be a real creator.

Yet all the difficulties have not disappeared. The conscious self is narrowly limited, and as for the subliminal self we know not its limitations, and this is why we are not too reluctant in supposing that it has been able in a short time to make more different combinations than the whole life of a conscious being could encompass. Yet these limitations exist. Is it likely that it is able to form all the possible combinations, whose number would frighten the imagination? Nevertheless that would seem necessary, because if it produces only a small part of these combinations, and if it makes them at random, there would be small chance that the *good*, the one we should choose, would be found among them.

Perhaps we ought to seek the explanation in that preliminary period of conscious work which always precedes all fruitful unconscious labor. Permit me a rough comparison. Figure the future elements of our combinations as something like the hooked atoms of Epicurus. During the complete repose of the mind, these atoms are motionless, they are, so to speak, hooked to the wall. . . .

On the other hand, during a period of apparent rest and unconscious work, certain of them are detached from the wall and put in motion. They flash in every direction through the space (I was about to say the room) where they are enclosed, as would, for example, a swarm of gnats or, if you prefer a more learned comparison, like the molecules of gas in the kinematic theory of gases. Then their mutual impacts may produce new combinations.

WHAT IS the role of the preliminary conscious work? It is evidently to mobilize certain of these atoms, to unhook them from the wall and put them in swing. We think we have done no good, because we have moved these elements a thousand different ways in seeking to assemble them, and have found no satisfactory aggregate. But, after this shaking up imposed upon them by our will, these atoms do not return to their primitive rest. They freely continue their dance.

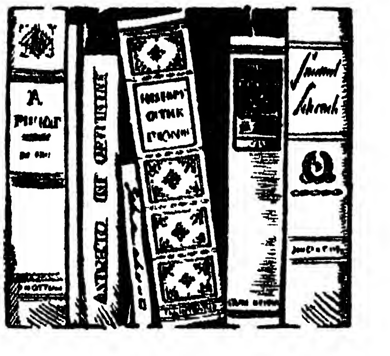
Now, our will did not choose them at random; it pursued a perfectly determined aim. The mobilized atoms are therefore not any atoms whatsoever; they are those from which we might reasonably expect the desired solution. Then the mobilized atoms undergo impacts which make them enter into combinations among themselves or with other atoms at rest which they struck against in their course. Again I beg pardon, my comparison is very rough, but I scarcely know how otherwise to make my thought understood.

However it may be, the only combinations that have a chance of forming are those where at least one of the elements is one of those atoms freely chosen by our will. Now, it is evidently among these that is found what I called the *good combination*. Perhaps this is a way of lessening the paradoxical in the original hypothesis. . . .

I shall make a last remark: when above I made certain personal observations, I spoke of a night of excitement when I worked in spite of myself. Such cases are frequent, and it is not necessary that the abnormal cerebral activity be caused by a physical excitant as in that I mentioned. It seems, in such cases, that one is present at his own unconscious work, made partially perceptible to the over-excited consciousness, yet without having changed its nature. Then we vaguely comprehend what distinguishes the two mechanisms or, if you wish, the working methods of the two egos. And the psychologic observations I have been able thus to make seem to me to confirm in their general outlines the views I have given.

Surely they have need of [confirmation], for they are and remain in spite of all very hypothetical: the interest of the questions is so great that I do not repent of having submitted them to the reader.

James R. Newman is an attorney and co-author (with Edward Kasner) of Mathematics and the Imagination



BOOKS

Arnold Toynbee's "Civilization on Trial": an analysis of the historian's statement of his views and methods

by Abram Kardiner

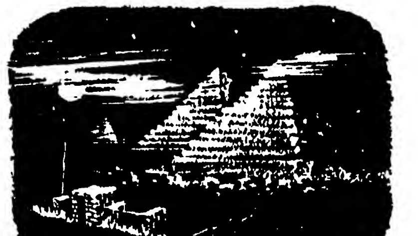
THE strange popularity of Arnold Toynbee, now much inflated, has received a fresh boost from his newly published "Civilization on Trial" (Oxford University Press). It is a popularity that needs to be explained. It cannot be due only to the attention Henry R. Luce has given him in the magazines *Time* and *Life*, nor to the timeliness and importance of the message conveyed by his book. It is more likely due to the desperate public need to get some bearings along the uncharted course of contemporary civilization from anyone who appears qualified to supply them. The Toynbee fad is not world-wide. His native England has not participated in it; only two of the thirteen essays in "Civilization on Trial" were delivered there. It is in the U. S. that Toynbee has become a prophet. His exertions appear to have been called forth largely by the anxiety of Americans.

This being the provocation, it cannot be said of Toynbee that he rose to the occasion. His message, for all its saccharine piety, has neither originality, conviction nor dignity. Perhaps the situation caught him off guard. Perhaps he had difficulty in adjusting his perspective from the telescopic view of history to the microscopic view of our troubled world

In any event Toynbee has little to say that the responsible student of human social adjustment can take seriously. In this book, as in his vast histories, he remains singularly uninfluenced by the recent advances in anthropology, psychology and sociology. We must hold him accountable for this ignorance. Were he acquainted with these disciplines, Toynbee could not in good conscience avoid using them for the particular subject matter we call "history." Nor could he with good grace argue the timeworn issue of whether our basic intellectual orientation should be scientific or theological.

What then do we find in Toynbee's approach to history? About this Toynbee here is all too candid—much more so than he is in his larger works. He freely tells us of his prejudices and predilections. And with little self-consciousness he tells us how he arrived at the master plan for his conception of history. It came about as a result of his education in the Bible and in the history and literature of Greece and Rome. Toynbee was also influenced somewhat by Oswald Spengler, but dismissed his conclusions because he provided no explanation for the rise, development and decline of civilizations. Spengler, says Toynbee, was too arbitrary and explained nothing. Toynbee rejects the German *a priori* method and offers English empiricism instead.

Toynbee set this empiricism to work on the principal keys of the 19th-century historians: race and environment, neither of which "unlocks the fast closed door of history." Then he turned to mythology, which somewhat embarrasses him. "Had I been acquainted with the works of C. J. Jung [a choice Mr. Toynbee does not explain], they would have given me the clue I actually found it in Goethe's *Faust*. . . . Because God's works are perfect, the Creator left himself no further scope for His creative powers, and there might have



been no way out of this impasse if Mephistopheles—created for this very purpose—had not challenged God to give him a free hand, to spoil, if he can, one of the Creator's chief works. God accepts the challenge and thereby wins an opportunity to carry His work of creation forward"

Toynbee's first "challenge and response" is thus a wager between God and the Devil, the latter being a creation of God so that He may be kept busy at the job of creating something new. In order to keep the game going "we are bound to assume that the Devil does not always lose." This is how Toynbee's challenge and response, the famous formula that supposedly explains the evolution of civilizations, came into being.

Toynbee feels that there are two ways of looking at history. One is the cyclic repetition of birth and death, accepted by the Greeks and Hindus. The second is the Jewish-Zoroastrian belief that history is a masterful and progressive execution of a divine plan that transcends comprehension. Toynbee settles for a happy fusion of both ideas. There are cycles and a divine plan. Man learns through suffering.

This master plan is a better conception for a literary epic than for an empirical study of history. It is a conception which insists that Toynbee be an unreliable observer and a prejudiced interpreter of facts. The most shocking aspect of Toynbee's master plan is that it takes man's fate out of his own hands, making history a mere sideshow of a divine game in which the motive forces are not concerned directly with man and hence are incomprehensible to him. It is a struggle between Ormuzd and Ahriman (the Zoroastrian spirits of Good and Evil) and is of no more interest than the fate of an anthill.

MAN, STATES Toynbee, may not discover the successes and failures of society by empirical research into the past and present, by examining the success or failure of different types of social organization. Nor may he study the role that psychological conflict and motivation play in social stability and social disintegration. Man must surrender all such grandiose presumptions and yield to a dogma, to the article of faith that God knows best.

In attempting to answer the question of where we now stand in history, after recounting the difficulties of deciding the relative merits of Russian and Western culture, Toynbee says: "Our cue may still be given by the message of Christianity and the other higher religions." If history merely repeats itself, we are doomed both by Toynbee and Spengler. We may, of course, try such stopgaps as world government, or vary free enterprise with socialism. This is all but incidental. Let us, advises Toynbee, put the secular superstructure of society back on a religious foundation. The technological scaffolding of Western society will fall away first because it was initiated in the 17th century as a reaction against 100 years of religious wars. This, says Toynbee, was a mistake. Society threw the baby out with the bath. In trying to free itself of wars it discarded religion.

It would be a great injustice to Toynbee if we did not examine the reasons that lead him to endorse this doctrine of hopelessness. He claims that there are five civilizations left in the world, each of which regards itself as the chosen order. Toynbee rejects a world confederacy. He finds a world state impossible without an exhausting war of conquest and a new *pax Romana*. The giants, the U. S. and Russia, are antagonistic to each other. Toynbee suggests a third power, essentially liberal and not committed to fighting socialism:

a Central Europe without Germany.

Toynbee is not altogether sure that this will work out well, because the world of the air age—transcending oceans, rivers and mountain ranges—may find a new center of gravity. This center will be determined by "human geography," *i.e.*, human numbers, energy, ability, skill and character. The rousing of the world's "neolithic peasantry" is only partly accomplished. It has yet to be effected among 1,500 million unawakened peasants, whose gravitational pull may set the center of the world back again in the vicinity of Babylon. This event will be heralded by a new religion.

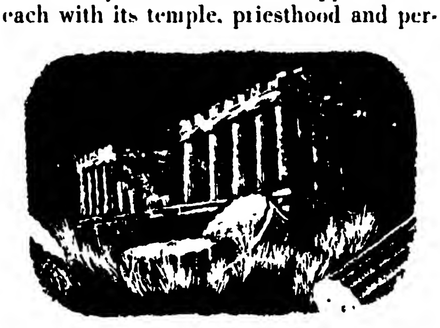
It is to religion that Toynbee assigns the job of unifying the world. There appears to be little real conviction in this belief, however, because his view of religion is not consistent. Religion is at once the only serious occupation of man, and "a transitional thing which bridges the gap between one civilization and another." Toynbee finds himself in a dilemma. He says "religion is subsidiary to the reproduction of secular civilization or . . . successive rises and falls of civilizations may be subsidiary to the growth of religion." He leans toward the latter.

TOYNBEE has thus made his position very clear, both in regard to the manner in which his histories are compiled, and in regard to his message for our troubled times. His histories are an arbitrary selection of historical patterns to prove a poetic conception of man's fate on this planet. He knew the master plan first and teaches his doctrine by historical parable.

In "Civilization on Trial" Toynbee proclaims his emotional bankruptcy. He ridicules all efforts to make man an object of scientific study, declares all efforts at political liberalism to be vain endeavors, condemns science as the pastime of fools. In place of all this he asks us to assume a faith he does not himself fully embrace, and asks us to put our trust in a course of action of whose outcome he is extremely uncertain. Toynbee has rationalized himself into the theological position by manipulating the hen-and-egg question of whether civilizations exist in order to give birth to "higher" religions or vice versa. His final decision is made on the basis of a personal bias. There is no logic in his facts because Toynbee doesn't know what factors determine the sequence of social events; nor does he ask any questions about the sequence. Having left himself ignorant of the noteworthy advances in anthropology and psychology, Toynbee argues his few facts with dated pedantry.

To Toynbee religion is not a social phenomenon that must be studied with detachment but a phenomenon that must be given extraterritorial rights. This is not a view to which anyone acquainted with the comparative study of religion can subscribe. The study of the religions of all peoples, primitive and civilized, shows that there is no such thing as a lower or a higher religion. The belief in a superior being who creates the world and man is universal to all religions. What is peculiar to each religion is the means of soliciting the aid of the deity or incurring its displeasure. And this is contingent upon the particular mores and customs that it is the business of religion to maintain. Hence as the mores vary, the religion varies. The so-called higher religions are not the products of what Toynbee calls "deeper religious insights"—whatever that may mean—but are always subservient to social necessities.

A case in point is the religion of Egypt. The political unification of Egypt was occasioned by the necessity to control the water supply of the Nile for purposes of irrigation. Bloody wars were fought for this unification. When the conquest was completed the local gods of the original 42 districts were merged into a hierarchy, but all of these original deities were included in the larger family of the gods. In other words the religion and its dogmas were subject to a synthetic elaboration. When the economic resources of Egypt were preëmpted by a small feudal aristocracy and used to build pyramids—each with its temple, priesthood and per-



petual endowment—the Egyptian economy crumbled. The result was a religious revolution and the elevation of Osiris, the god of suffering, to the status of chief deity. Osiris was the champion of the suffering masses. And with his elevation came the democratization of post-mortem rights, heretofore the privilege of the elite. So the masses won their illusion—the right to happiness after death.

This was indeed a religion created by a recalcitrant proletariat; this time an internal proletariat, to use Toynbee's classification. But there is no evidence that the Osirian revolution brought any social reforms. The rise of Christianity was likewise a movement of oppressed masses within the framework of the Roman Empire. No social reforms were possible; the masses had to be satisfied with post-mortem progress.

Even the "higher" religions change. From Job to Calvin we see a steady evolution within a fixed ideological framework. And religions always change in accordance with certain social pressures and needs which they express. For religion indeed has the very important function of stabilizing the social order.

If we adopt this point of view of the social function of religion, it is easy to deduce what it was that displaced its authority. It was not depravity and wanton irreligiosity, but the fact that, for a time at least, human anxiety was diminished sufficiently for the secular state to take over some of the functions once delegated to the church. Salvation was replaced by the ability of social organization to satisfy human needs.

Now that this brief interlude in human affairs appears to be drawing to a close, Toynbee wishes us to recreate social stability by the fantasies of 2,000 years ago, of which only the shadow lives today. This reviewer submits that it is not altogether ethical for our time to recommend that social stability be maintained by fear of the supernatural, while exonerating human society from its share in the creation of suffering.

IF I JUDGE the temper of the time correctly, I do not think that Arnold Toynbee's exhortations are presently in order, or that the illusive satisfactions promised after death will get much of a following. Temporal success, a higher standard of living and freedom from material anxiety are the only currency for social remedies today. To this challenge Toynbee replies by denying the problem, by inviting us to retreat from reason and to surrender to supernatural power. He claims that the ultimate ends of human life are beyond the reach of human judgment. John Dewey, in his "Problems of Men," answers this thesis adequately. "In a time as troubled as the present, a philosophy which denies the existence of any natural and human means of determining judgments as to what is good and evil, will work to the benefit of those who hold that they have in their possession superhuman and supernatural means for infallible ascertainment of ultimate ends, especially as they also claim to possess the practical agencies for ensuring the attainment of final good by men who accept the truths they declare."

And so we come away from Arnold Toynbee's book much disillusioned, but a little grateful that he has so completely revealed himself. Who would have thought that if you scratched Toynbee you would find an epic poet and a missionary? About his explanation of the rise and fall of cultures, the reviewer feels much as he did as a child when his father taught him nursery rhymes at bedtime. The one that baffled him most ran: "The King of France with forty thousand men marched up the hill and then marched down again." The child insisted on knowing why the king marched up the hill and down again. To which his father always said, "Go to sleep."

Abram Kardiner is associate professor of clinical psychology, Columbia University.

THE AMATEUR

Conducted by Albert G. Ingalls

MAKING a telescope eyepiece lens of the simple, old-fashioned Coddington type is "an interesting and instructive experiment," writes John M. Holeman of Richland, Wash., "which is so unusual it should be worth trying. I have just finished trying it. I had some fun and the oculars made are not nearly so bad as anticipated." Invited to describe his adventure, Holeman wrote the following:

First of all, a piece of optical glass is cut down by sawing, chipping, or grinding to an approximate sphere perhaps 7/8-inch in diameter. The source of glass may be an old lens or prism or a chunk of rolled optical glass—borosilicate crown. (War surplus prism blanks sell for a few cents.)

If handy, a wet glazier's abrasive belt sander will make quick work of it. Or the chunk may be rubbed to a rough ball on another piece of glass or metal with coarse abrasive grains and water.

The ball is now ground to a perfect sphere by the method which has been used in China for thousands of years to make quartz gazing crystals. The method is still used by German lapidaries to make agate marbles. The rough sphere is ground between two brass tubes charged with Carbo. The tubes should have walls from about 1/16-inch to 1/32-inch thick and have a diameter two thirds that of the rough sphere of glass. One tube is fastened to a vertical spindle and rotated at moderate speed by a motor. The ball is placed on top of this tube. The other tube is of the same size and is held on top of the sphere at an angle of about 15 degrees. The sphere is charged by means of a paintbrush dipped in coarse Carbo and water. Carbo embeds itself in the soft brass and cuts the glass on a curve. The ball then rotates and is cut on all surfaces by the two tubes. This is the principle of the lens generator, the modern machine which makes spherical surfaces, and of the centerless grinder.

The more the ball rolls the smaller and rounder it becomes. If you did a poor job of shaping the original rough sphere and

Steps in making a Coddington lens

ASTRONOMER

tried to work a jagged chunk having sharp corners and deep fissures you may take solace in the original Chinese treatise on gazing balls which, translated, states: "The going may be a little rough at first but it will soon settle down."

To those who may ask whether the ball gets smaller faster than it gets rounder I can offer the accompanying table of figures on one I made. Grinding was started at 9:30 o'clock and proceeded with interruptions for changing abrasive and making measurements as shown. "Max. diam." was the diameter in inches across the longest axis and "Min. diam." the shortest. "Difference" is the difference between the two measurements and shows how nearly round the sphere was. The table shows that while the sphere loses size it gets

Time	Max. diam.	Min. diam.	Difference	Abrasive
10:00	.820	.797	.023	No. 100
10:05	.813	.793	020	No. 250
10:12	.809	790	.019	Same
10:20	.802	788	.014	Same
10:32	.798	786	012	Same
10:37	.792	.7835	.0085	Same
10:43	.788	.781	.007	Same
10:48	.7845	.779	.0055	Same
11:00	7785	776	0025	Same
11:07	.7740	.7730	.0010	No. 500
11:10	7735	.7724	0009	Same
11:13	.7226	7220	.0006	Fine Emery
11:15	.7217	.7215	.0002	Same
11:30	.7213	.7212	.0001	Same
11:45	.7211	.7211	.0000	Rouge

rounder much faster than it gets smaller. By continuing the process a reasonable length of time the shape should become perfect so far as can be measured. The table also shows the approximate length of time needed to grind a sphere ¾-inch in diameter.

Polishing was done as follows. The lower tube was cleaned and heated with a flame until pitch would melt on it, then a thick rim of hot pitch was built up around the edge. While the pitch was still soft a washer of felt, cut out of an old hat, was pressed down on the rim and held in shape by the ground sphere. The top tube was later treated the same way, so that both tools now had a rim of felt attached to their working surfaces. To polish, the felt was charged with rouge and water, and polishing went as with grinding, but more smoothly. Ten minutes gives a good polish.

Now we have a perfect glass sphere which could be used "as is," especially if it is a smaller size. But for larger sizes (and I suggest trying these first) it had better be made into a Coddington lens. The right cylinder diameter for a Cod-

dington ¾-inch long is about ⅜ inch. To make this, a piece of wooden dowel ⅜-inch in diameter was concaved on one end to fit the sphere and the sphere was cemented to it with hard pitch. Now a "cookie cutter" charged with medium Carbo was brought down on it in a drill press and a cylinder was cut out of the sphere.

THE FINAL operation, after removing the waste from the sphere, is cutting the Coddington field stop. Leaving the cylinder of glass still cemented to the dowel, the glass is rotated against a thin edge of metal or other sheeting armed with abrasive and a thin groove is cut around the cylinder to a constant depth, stopping when the groove begins to infringe on the field. This groove, when blackened with India ink or paint, acts as an aperture stop, giving a sharp edge to the field and removing the poorly lighted and poorly defined marginal rays.

It is interesting to see how small an ocular can be made by this method. If anyone completes one less than 4 mm. in diameter I hope he will let me know and I will send him the straitjacket I am now wearing.

I found that long-focus Coddingtons, which are easier to make, were poor. The one made from a ¾-inch sphere had a field of about 40 degrees of which only about 20 degrees was good. There was much aberration and color at the edges. Eye relief was satisfactory at about ½ inch and seeing in the center was fine. The best one I made has an effective focal length of .31 inch, an angular field of 40 degrees, an eye relief of .2 inch and is usable with eyeglasses. The definition is good, there is no color, and it is grooved down to about a .3-inch waist. It is the best short-focus ocular I have used. The shortest I have completed is .22-inch focus but it didn't turn out well, though it is usable provided you really want an ocular of that short focal length. If we now go a step further and regard the solid ocular as the "triplet" field lens of an orthoscopic ocular and add a plano-convex lens, flat side toward the eye, we have a fairly good imitation orthoscopic design with a larger usable field and more eye relief. For example, if the solid ocular made from the ¾-inch sphere mentioned above is used in conjunction with a plano-convex lens of about 1½-inch focal length and with a spacing of about ¼ inch between the two, a considerable improvement will be noted in the marginal definition. The resulting eyepiece will be no world beater, but usable.

End of Holeman's contribution.

If the Coddington is approached with great expectations, the probable reaction, unless the worker is objective in his estimate, will be that it is no good at all. But if no miracle is expected the result may equal or surpass the expectation. The project was undertaken by Holeman as a kind of sporting adventure to see whether

the very old-fashioned ocular might not have more merit than might be thought, and so it proved. Bell, in *The Telescope*, rates the Coddington as somewhat better than a simple lens.

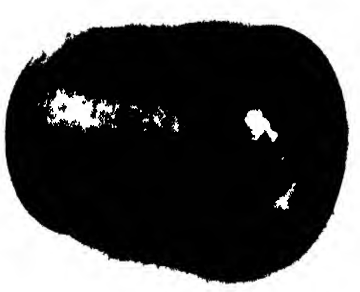
ANOTHER adventure in the unusual is the modern attempt to duplicate some of the tiny high-power eyepiece lenses made by the great Sir William Herschel (1738-1822). These were described in the *Transactions of the Optical Society* (London), Volume 26, by W. H. Steavenson, F.R.A.S., a prominent member of the mainly amateur British Astronomical Association. Steavenson has kindly furnished two of the photographs originally published in that periodical. He visited the old Herschel home, examined and carefully tested many of Herschel's mirrors and flats, also the famous "seven-foot" reflector (7 feet, 2³/₄-inch focal length, 6.2-inch aperture) so often mentioned in Herschel's writings. In the *Transactions* Steavenson writes:

".01 INCH.

In comparison a pinhead is huge

"Herschel's claims to have used powers between 1,000 and 6,000 on his seven-foot telescopes have been the subject of some controversy and not a little incredulity in the past. It therefore seemed to be of particular interest to find out whether he really possessed eyepieces which would yield such powers as these. Quite a short search sufficed to lay any doubts at rest by revealing no less than nine of these eyepieces, whose focal lengths and powers (on the telescope used by Herschel) were found by careful measurement to be as given in the table.

ONE INCH



Herschel's highest-powered eyepiece

"All these are well-formed bi-convex lenses, with the exception of D_{21} [*identifying notation—Ed.*], which is a simple sphere. Two or three of them, including the smallest, were found to be somewhat astigmatic, and in some cases there were signs of devitrification of the surfaces; but in general they gave sharp images in the micro-focometer used, and their focal lengths were quite readily measured.

"All were tested on celestial objects with a six-inch Wray refractor and were found to form recognizable (though of course dim and diffuse) images of stars and planets. Even D_{21}, despite astigmatism and excessive power (about 10,000 diameters) showed the spurious disk of Vega, with portions of the first diffraction ring, and also exhibited the general outlines of the planet Saturn. The field of view was, however, only about 20 seconds of arc in diameter, and the image could hardly have been examined, or even held in view, without the help of a good clock drive. And yet Herschel, in his experiments on high powers, had nothing better than an altazimuth stand with hand-driven slow motions!

"We are told nothing of the methods employed in making these tiny lenses, the smallest of which is only ¹/₁₅-inch in diameter. Compared with this, the front lens of a modern 2 mm. oil-immersion objective is a large and clumsy object. It would be interesting to know exactly how a present-day optician would proceed, if required to make a duplicate of the most powerful of Herschel's eyepieces, fashioned in the 18th Century."

In the illustration of the eyepiece, what may look like the lens is the eye end of the eyepiece shell. On that shell is a raised nipple. On the tip of the nipple is a tiny dot, just visible. This dot is the wee lens shown in the other illustration, its diameter one third that of a pinhead.

Herschel's trick eyepieces may have been made by him partly as a stunt. So thinks his granddaughter, Constance A. Lubbock, editor of *The Herschel Chronicle*. Herschel was ever a case of "once an amateur always an amateur," which carries with it an incurable interest in stunts done purely for the fun of it. He probably wanted to see just how small a lens he could make, and probably as he made those described he chuckled, "I'll give 'em 160 years to beat me on these."

If Herschel came to life today, where would you expect to find him after he had explored our optical world? Among professionals (the few remaining who didn't start as amateurs), or down in some amateur telescope maker's cellar shop having fun? New York's Amateur Astronomers Association recently asked this department whether Russell Porter, as one who has associated with astronomers for the better part of his life, might not quite approve the award to him of its Amateurs Medal for meritorious service to the science of astronomy. The answer was, "Never has Porter thought of himself as anything else than an amateur." The amateur's cellar shop in which to look for Herschel would be Porter's.

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LETTERS

Sirs:

May I draw your attention to an omission in Bela Schick's excellent article on allergy, published in your July issue?

Dr. Schick states that the discovery of anaphylaxis was made by the famous physiologist Charles Richet. Actually the discovery was made by *two* famous physiologists. One of them, Richet, was already famous at that time. The other, Paul Portier, became just as famous some years later. In fact, the discovery often bears the name Richet-Portier.

I am not able to discuss which of the two scientists made the more valuable contribution. But I might point out that Dr. Portier, who happens to be an old friend of mine, was at the same time professor of physiology at the Sorbonne and at the Paris Institut Océanographique (founded by Prince Albert Ier de Monaco); that he is a member of the Academy of Sciences (Institut de France) and of the Academy of Medicine, a dual distinction very rare in France; that now being 84 years of age he has retired to Bar-sur-Seine (Aube, France), though he still writes, lectures and leads his former pupils in the field of physiology by his advice and deep knowledge.

Among physiologists, Dr. Portier is considered by many as the foremost figure. If I am asking you to kindly correct above mentioned omission, it is not only out of admiration for my old master, but out of respect for truth.

LUCIEN L. POHL

New York, N. Y.

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Sirs:

I have just finished reading with considerable interest the article in the July number of your magazine by Lorus J. and Margery J. Milne entitled "Insect Vision." I think the presentation of this article is such as to give the layman a very good picture of the mechanism of insect vision. There are, however, a couple of statements that I think require correction. The more serious of these occurs when the authors are discussing the ability of bees to distinguish flicker. They state: "Those who have experienced the uneven illumination of lamps run on electric power generated at Niagara Falls know that their fluttering at the rate of 50 flickers per second is only barely perceptible." I am not familiar with the power generated on the American side of Niagara Falls and it may be 50' cycles per second. On the Canadian side the power is generated at 25 cycles and throughout the whole area of southwestern Ontario the flickering is quite perceptible. Assuming, as the Milnes have, that an insect can recognize the direction of movement of stripes at 60 per second and that the human eye can distinguish fluctuation in 50-cycle current, of which I am not too sure, then the human eye is 50 times more effective than is the bee's eye. I know from experience, as mentioned above, that 25-cycle current is quite obvious to the human eye, thus making the latter 25 times as efficient as the insect's eye.

The question of vision in the ultraviolet, I feel, is dismissed somewhat too summarily. Some years ago, while carrying out studies on the reactions of the housefly to different wavelengths of light, I found that I personally could distinguish the 3132 Angstrom unit light in the mercury arc spectrum. At first I believed I was seeing stray images from the visible spectrum, but when I found that I could put this wavelength accurately on the scale of a large spectrograph, I was convinced that I was seeing ultraviolet light. In checking over the literature, I

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found several references to various other investigators who could also see varying distances into the ultraviolet spectrum. I admit that human vision in this region is not common and certainly nowhere nearly as efficient as that of many insects; nevertheless, it does exist and should be recognized.

The above is in no sense a criticism of the paper on insect vision but I thought it worthwhile to draw your attention to these two points.

J. M. CAMERON

Forest Insect Laboratory
Sault Ste. Marie, Ontario
Canada

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Sirs:

As a professional pianist, may I object to a statement in the article "Physics and Music" in your July issue, namely "the tone (of a piano) is exactly the same whether the key is pressed by the finger of a great artist or by the tip of an umbrella"! If that is true, how does the author, Dr. Frederick A. Saunders, account for the difference in the tonal quality of the same piano played by three or more persons on the same program? Or does he hear the difference? Tone is the result of weight at the moment of attack—after that the tone can be altered slightly only by a pedal trick or by intoning the primary harmonics.

MARIE MIKOVA

Los Angeles, Calif.

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Sirs:

Presumably all correspondents are entitled to their own opinions. I note that one of your Iowa correspondents in the July issue is bemoaning the passing of "the finest shop and hobby magazine in the world." I trust that the editors are not unduly disturbed by such lachrymation. From what I hear it is not so much a revolution as a return to the earlier ideals of scientific coverage held by the *Scientific American* some "50 and 100 years ago."

It's not as though there weren't a vast rash of shop-and-hobby grease-and-grime sheets on the stands to which the frustrated mechanics can resort! But as one of your June correspondents points out, if it continues as it is going, the *Scientific American* will fill a critical gap in American publications—the *only* one of its kind in the field which it *now* so adequately and lucidly covers.

DEAN KELLEY

Denver, Colo.

50 AND 100 YEARS AGO

SEPTEMBER 1898. "Saturday, August 20, was a red-letter day in the history of New York City, for when the seven armored warships of Admiral Sampson's fleet, fresh from the smoke of battle and bearing the scars of a victorious struggle, steamed in stately line up the North River. New Yorkers gazed upon a sight the like of which no city has ever witnessed before."

"Mr. William Ogilvie, chief of the geographical survey of Northwestern Canada, declares the Yukon gold fields extend over more than 125,000 miles of territory. Other precious metals are to be found in the same district; there is also coal, petroleum, and other products, awaiting only the means of securing and transporting to market."

"How do carrier pigeons find their way? This question has been often discussed. M. Pierre Bonnier gives us the result of the latest investigations on the subject. He tells us that pigeons and other 'homing' creatures find their way by no special sense, but merely by a high development of the power of 'keeping their bearings,' even in darkness, which all animals, even man, have in some degree, however small. This power he believes to depend on the construction of the inner ear."

"Of late have sprung into existence a number of preparations, claiming to be safe and efficient food preservatives. Within a few months, several cases of severe and dangerous poisoning, as the result of the employment of boracic acid and borax, have been chronicled in the medical press, both of America and abroad. It is evident that too much circumspection cannot be employed as regards the use of so-called food preservatives, and that as a rule such should be regarded with the utmost suspicion, particularly if their exact composition or contents is unknown."

"Three weeks ago we felt it incumbent upon us to protest against the wanton waste of life that was taking place as the result of the criminal incompetency of the War Department. Events that have transpired in the interim have merely served to strengthen our conviction that a shameful wrong has been done in the wholesale and altogether unnecessary sacrifice of the lives of hundreds, if not thousands, of our soldiers. The disgraceful inefficiency of Siboney and Santiago has now been repeated at Montauk; and the men who fought so bravely, even if unfed and unattended at the front, are now coming home, many of them to die—to die, not of disease, but as the attendant physician of poor young Tiffany said, of 'starvation, due to the fact that' they 'did not have food that was suitable to the conditions of a convalescent.' "

SEPTEMBER 1848. "News has reached us from California, of the discovery of an immense bed of gold of *one hundred* miles in extent, on American Fork and Feather rivers, tributaries of the Sacramento, near Monterey. Mr. Colton, the Alcalde of Monterey, states that the gold is found in the sands, in grains resembling squirrel shot, flattened out. Some grains weigh an ounce each. It is got by washing out the sand in a vessel, from a tea saucer to a warming pan. A single person can gather an ounce or two in a day, and some even a hundred dollars worth. Two thousand whites and as many Indians are on the ground. All the American settlements are deserted, and farming nearly suspended. The women only remain in the settlements."

"The American Association for the Advancement of Science has been sitting in Philadelphia during this and part of last week. We are proud and happy to see such associations among us—they do much for the advancement of civilization. In Britain there is an association of the same kind which has done wonders not only in advancing science, but in elevating man—by bringing together eminent men from all nations, and spreading among them a generous feeling to one another—making them feel that men of science are the property of the whole human family."

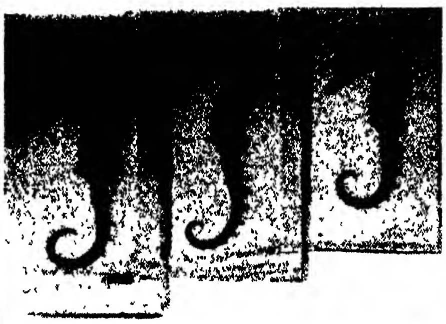
"Wisconsin makes the 30th State of the Confederacy. It contains some 90,000 square miles of territory—two thirds larger than all New England."

"The startling idea of spontaneous generation of animalcules has been broached. What favors the supposition of animalcules being deposited either in the germal state, or from their bodies being dried up and floating in the air, is the fact, that in a series of well-conducted experiments, performed by Schulze some years ago, where water was distilled and well boiled, in order to destroy any animal life it might contain, and vegetables, for the same reason, exposed to the heat of an oven, and the air admitted to the vessel, which was hermetically sealed, through strong sulphuric acid: on the vessel being placed in the sun, after the lapse of some time, not a single animalcule could be detected, though a jar by its side, made of the same materials, but open to the atmosphere, was found to swarm with living beings."

"On a motion for an injunction on the Electric Telegraph used by Henry O'Reilly, as an infringement of Morse's patent, a most interesting examination into the merits and priority of Morse's invention was had and a decision made on the 9th inst., awarding an absolute injunction. The trial was had in Frankfort, Kentucky, and eminent counsel were engaged on both sides. The utmost range of objection was taken by O'Reilly's counsel, some of which displayed not a little meanness, such as the objection that 'part of the improvement claimed had been in use prior to a patent being secured, with the consent of the patentee.' There is nothing that fills us with more indignation than an attempt to nullify the exclusive right of an inventor to his own invention, by the objection of '*using*' it before it was patented."

"An English aeronaut named Coxwell is demonstrating a novel system of aerial warfare at Elberfield, Prussia. On the 17th of July he ascended, in company with a German gentleman, and, when the balloon had attained a considerable altitude he descended and commenced a sham bombardment of the town beneath him. This performance in mid air at once amazed and amused the spectators, whilst a party of scientific gentlemen decided that the ingenious plans of Mr. Coxwell might prove available for immensely useful purposes in actual warfare."

"We are happy to learn that the foundation of the Washington National Monument is moving upward as rapidly as the nature of such a work will admit. It is eighty feet square, and of solid stone. The masonry is said to be so far, most skillfully and carefully executed, and promises to do great credit to all concerned in the erection of this magnificent memorial of the gratitude of the American people to the illustrious Father of his country."



THE COVER

The painting on this month's cover shows a collection of the devices used by the medicine men of primitive societies (*see page 24*). At the upper left is a grotesque mask used by the Iroquois Indians. At the lower left is a white rooster sacrificed in medical ceremonies of a West Indian tribe. The black object at the lower left is a medicine knife used by the Yurok Indians of the U.S. Northwest. In the center is a skull trephined by Peruvian Indians. Below it is a medicine rattle employed by the Tlingit of the Northwest. At the right is a fetish of the natives of West Africa. At the lower right are bone tubes used by the Menomini of the Northeast, and the leaves of cocaine, applied in South America.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

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9	Courtesy *World Oil*
10	Eric Mose
11	Courtesy *World Oil*
12-14	Eric Mose
15	Courtesy *World Oil*
16	Eric Schaal
17	Eric Mose
19	Eric Schaal (*top*), Eric Mose (*bottom*)
20	Eric Schaal (*top*), Eric Mose (*bottom*)
21	Eric Mose
22-23	Jon Brenneis
24	From *Navajo Medicine Man* by Gladys A. Reichart. Published by J. J. Augustin, N. Y.
26-27	K. Chester
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49	Ramon Gordon
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60	Russell W. Porter

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Happy hunting ground for a fish

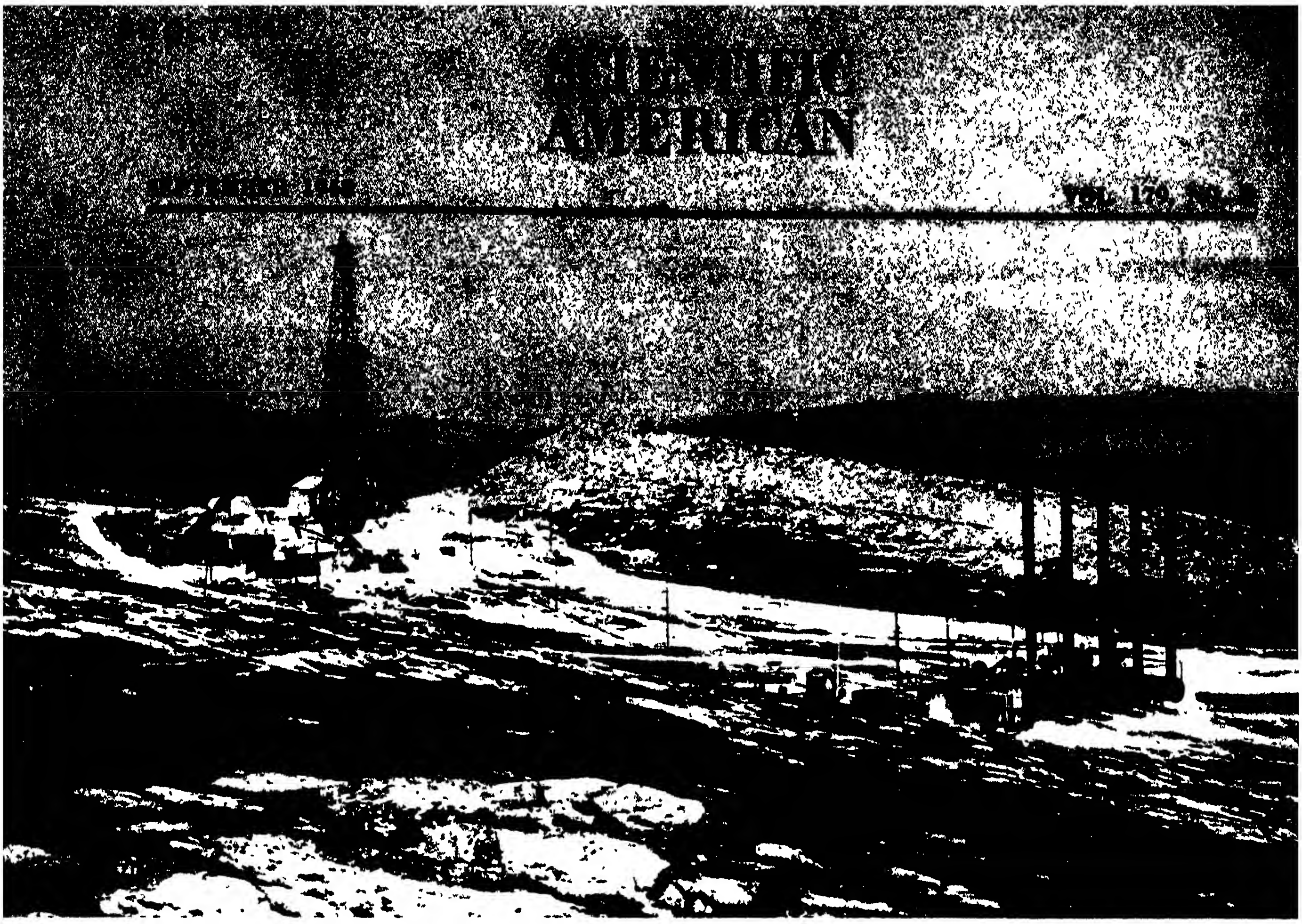
WHEN HE PLANTED corn and tobacco, the Indian ceremoniously buried a dead fish with the seed. To him, it was an offering to the gods. Today we know it was also sound chemistry. Decaying animal matter restores a vital element to the soil—nitrogen. Without it, crops won't grow.

It would take all the fish in the sea to supply the industries which depend today on nitrogen. So we make it synthetically from ammonia. Familiar to you as the nose-tickling household compound that makes windows gleaming clean, ammonia performs a host of jobs in agriculture and industry. It helps make such products as the dry-cell battery, synthetic rubber, and textiles.

Last year, CSC purchased the Dixie Ordnance Works from the War Assets Administration. Today, this plant is working at capacity to produce ammonia for agriculture and industry. Ammonia is one of more than 200 CSC chemicals for the farmer, the manufacturer, the doctor, the motorist.

CSC

COMMERCIAL SOLVENTS CORPORATION, 17 EAST 42ND STREET, NEW YORK 17, N. Y.



DESERT OIL WELL stands in the Lali field of southern Iran. The daily output of this well is 22,500 barrels. The average output of oil wells in the Middle East is 2,000 to 15,000 barrels a day. Some wells produce as much as 50,000 barrels. In the intensively worked U. S. the average output of a well is only 12 barrels of petroleum a day.

MIDDLE EAST OIL

The richest of all the great petroleum regions, just beginning to revise the world fuel economy, is the bequest of a remarkable geologic history

by F. Julius Fohs

IN THE oil fields of the Middle East, the average output of crude per well is 2,000 to 15,000 barrels a day. Some wells produce as much as 50,000 barrels a day. The magnitude of this bonanza may be measured by the fact that in the U.S., which for half a century has produced a great deal more oil than the rest of the world put together, the average well yields only 12 barrels a day, and only occasional wells can efficiently exceed a daily limit of 1,100 barrels. The comparatively few wells drilled so far in the Middle East show that the region harbors the richest concentrations of petroleum on earth. Its probable reserves (proved or partly proved) already are known to exceed those of any other region.

The discovery of this vast wealth of oil enhances the great strategic importance which the Middle East has long possessed for cultural and geographical reasons. Culturally, it is the birthplace of Western civilization and the home of three great world religions. Here originated the first written language, the architectural forms of the pyramid, colonnade, arch, tower and spire, and the earliest finished sculpture. Here too were developed the first practical arts: metal-working, weaving, paper-making as well as the first roads, bridges, seagoing ships and irrigation works. Geographically, the Middle East is the only link between the land masses of Africa and Eurasia. It is also the site

of the most important single link in the world's waterways—the Suez Canal—and it is a world air crossroads, for any all-weather global airline must pass through it. To these various reasons for the interest of the principal nations in the Middle East, there is added a political one: Palestine. The Jews, unwanted by other countries, have been forced to migrate there and to fight to maintain the new state of Israel and its right to permit immigration. Fundamentally, however, all strategic considerations and problems in the Middle East are profoundly affected by its abundance of petroleum.

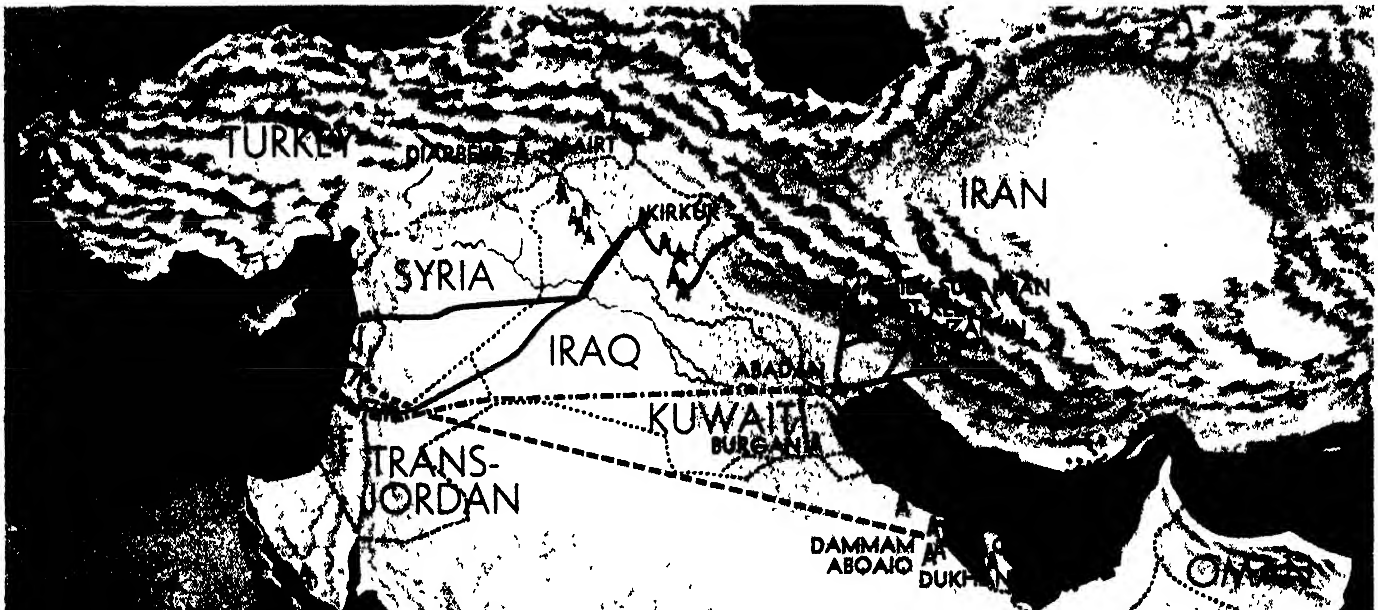
The Middle East consists primarily of the defunct Turkish Empire plus Iran (Persia) and Afghanistan. It covers an area of 2,853,000 square miles and has a population of about 82 million. Of this total the Arab States (Egypt, Iraq, Lebanon, Syria, Latakia, Trans-Jordan, Saudi Arabia and the adjacent sheikdoms of Kuwait, Bahrein, Oman, Qatar, Yemen, etc.) account for an area of 1,681,000 square miles with a population of some 36 million, while the new state of Israel covers 5,500 square miles. The surface of the region is economically unattractive. Rain, which comes in the season from November to February, falls only on the mountains and higher plateaus, and decreases greatly south of the 32nd parallel—about the latitude of Dallas, Tex. Because of great heat and evaporation, much of the region consists of vast desert areas.

The principal surface features of the Middle East are: 1) plateau lands and a group of low mountains paralleling the eastern Mediterranean coast; 2) the Asiatic Alps, which consist of the Taurus and Zagros ranges, lying across southern Turkey and western Iran; and 3) the Elburz Mountains in northern Iran, bordering the Caspian Sea. Between the Taurus-Zagros ranges and the western part of Saudi Arabia, extending from the northwest to the southeast down through the Persian Gulf, lies a broad basin which is the site of the great oil pools (*see map below*).

Origin of Persian Gulf Oil

About 500 million years ago, the Persian Gulf area was part of a broad, shallow sea which had become landlocked, possibly by mountains closing the Gulf. In tropical heat the water evaporated, leaving huge beds of salt. This was in Middle Cambrian time. The history of this sea is revealed to us by salt domes in the folds of the Zagros Mountains and in the basin to the southwest. These domes are made up of salt from great depths, together with remnants of ancient Cambrian shales and sandstones.

Over the Cambrian rocks and the salt beds, a series of limestone layers containing dead plants and organisms began to be deposited in another shallow sea about 155 million years ago. These marine beds, each more than 1,000 feet thick, constitute both the principal material from which the oil was formed and the reservoir rock in which it was trapped. The alternation of shallow and deeper seas, with the formation of lagoons, was just the right background for the creation and accumulation of oil. Bituminous shales and thin limestones, foraminiferal limestones, coral-reef and bryozoan-reef deposits and dolomites were laid down in the seas, alternating with anhydrite, gypsum, salt, muds and limy shales. Present-day borings show that these deposits continued from the Jurassic to the Eocene



EXTENT of the oil regions of the Middle East is indicated by blue areas on this map. The region lying about the Persian Gulf was the bed of an ancient sea. Sediments left by the sea were folded, trapping oil, when the land mass to the north and northeast moved towards the Red Sea. The axis of the folds created by this movement of the earth's crust is indicated by the heavy white line running approximately parallel to the Persian Gulf.

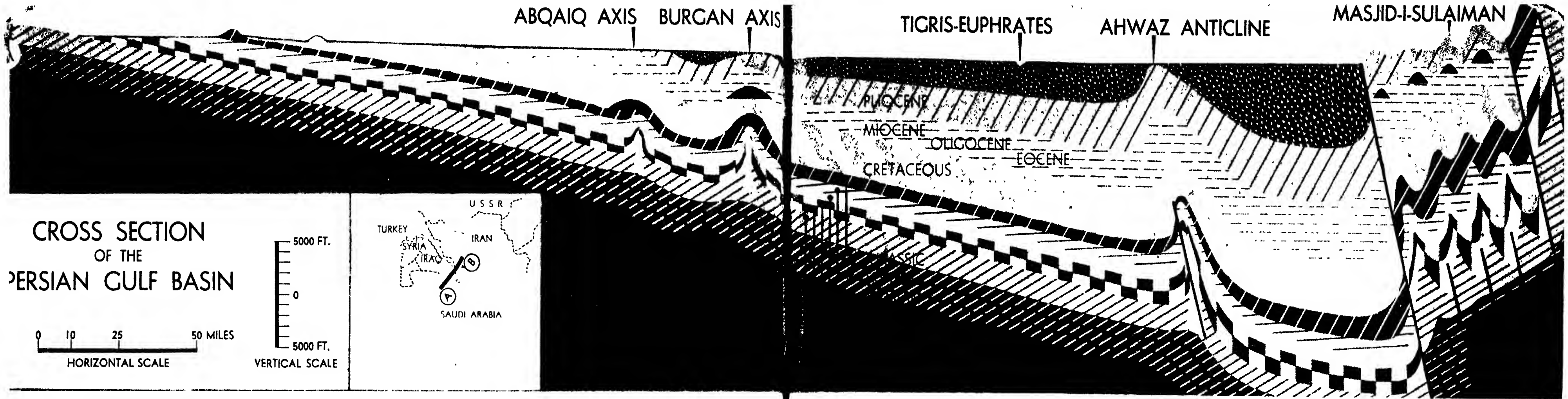
geological period, or from 155 to 35 million years ago. Then, in the last 7 to 10 million years, layers of shales and sands were deposited above the oil-bearing strata to a depth of 1,000 to 15,000 feet. These layers formed an impermeable cover that sealed the oil reservoirs and prevented the escape of everything but a certain amount of asphalt and natural gas. Under the weight of the successive deposits, the basin gradually sank; at its eastern end the strata may reach a thickness of 30,000 feet (*see diagram on pages 12 and 13*).

These unusually favorable conditions for the accumulation of oil were followed by movements of the earth's crust that trapped the oil in big pools. Oil generally concentrates at the crests of underground folds (anticlines) in strata of porous rock; the oil in the rocks, being lighter than water, rises to the top of a fold and is held there by the water beneath it. In the Persian Gulf area a massive folding movement took place. It originated in the Turkish-Persian plateau region of the north and northeast—a semi-rigid land mass. This mass shifted south-southeast towards the Red Sea. Across its path, however, lay the Arabian shield, a rigid mass of ancient Cambrian, Ordovician and even older rocks similar to the shield of eastern Canada. The result of the plateau's movement against this immovable shield was an accordionlike folding of the basin between them. The principal fold formed the Taurus and Zagros Alps. In the softer strata of the main basin west of these mountains a series of smaller underground folds was created. It is these sealed domelike folds that constitute the major traps for Middle East oil. The folds generally run northwest to southeast, parallel to the main axis of the basin. They vary from two to 65 miles in length and from one to six miles in width. In eastern Iraq alone, 14 such folds jut above the surface as "whalebacks."

The ancient salt beds which lie beneath the limestones also assisted in trapping oil. Salt domes are created when a bed of deep-lying salt, starting along a fault or fracture during a period of major earth movements, is extruded into the strata above it. The fluid salt tends to arch the overlying beds; it may produce simple arching, it may partly pierce the beds or it may form mounds on the surface from which the salt flows in a "glacier." Because the salt domes of the Persian Gulf region rose chiefly through rigid strata that permitted underground fluids to escape, accumulations of oil are less likely to be found in them than on the U.S. Gulf coast or in Rumania, where salt domes are pushed up into soft strata that remain sealed. In the shallower parts of the Persian Gulf Basin, however, long folds were formed instead of domes; the vertical upthrust of salt combined with mountain-building compressive movements of the earth to create such folds.

"WHALEBACK" formation of the Middle East is one of the long folds that were created during the buckling of the entire region. Most of the folds are concealed beneath the surface. Oil, separating from water, is generally trapped in the strata of porous rocks at the crests of these underground folds.

PIPELINE carries oil of the Abqaiq field in Saudi Arabia to the Persian Gulf. In the background are the Arabian American Oil Company's derricks and tanks. The Abqaiq field already covers 23,000 acres, and its limits are not yet established. Five drilling rigs are now at work extending the field.



PROFILE of Middle East rocks shows the geological basis of its wealth of oil. Oil is indicated by the dark pools at the crests of underground folds. These folds were produced by a movement of the earth's crust from right to left. Folds at the left have been pushed up by salt. Location of this cross section is indicated by the letters A and B at left and right. These letters are keyed to heavy line in the small map which is inset at the left.

All the folds, as the gravity meter shows, are surrounded by heavier strata which confirm them as salt folds. Oil fields are easily developed on them; salt domes on the other hand are risky drilling investments.

The Fields

The producing fields of the Middle East (*see map on page 10*) fall into two principal groups: 1) those on the steep eastern slope of the basin, north and northeast of the Persian Gulf, including the fields of Diarbekr and Saint Quarqah and Kirkuk, Masjid-i-Sulaiman, Haft Kel and Pozanum; 2) those on the gentler western slope, on a shelflike rise west of the Gulf, including Burgan, Abu Hydra, Damman, Buqqa, Abqaiq, Qatif, the island of Bahrein and the peninsula of Qatar.

All these fields are located on whaleback folds. Their proved areas range from a few thousand to 83,500 acres. The oil is tapped from the crests of folds at depths from 950 to 7,500 feet. Except at Burgan, where the reservoir beds are a porous and permeable sandstone, all the fields are producing oil from limestone. Some of the fields, surprisingly, show heavy yields from dolomite with only 10 per cent porosity and with low permeability (lack of communication between pores). The dolomites are fractured, however, with tiny fissures. The method by which such rocks can hold and yield large amounts of oil has recently been demonstrated by H. S. Gibson of Anglo-Iranian Oil Company. Analyzing limestone cores from the wells on Masjid-i-Sulaiman and from outcrops on Asmari Mountain, Gibson showed that the pores carried 80 per cent of the oil and the fissures 20 per cent. The oil is held tightly in place by hydrostatic pressure, but when wells are drilled the release of pressure and expansion of the gas contained in the oil drives the oil to the well bores and a flowing well results. The oil at the crest of the fold at Masjid-i-Sulaiman was reached by wells at 1,200 feet. The water level in wells at the edge of the field was 1,000 feet lower; thus the thickness of the oil-bearing strata at the center of the field was 1,000 feet.

The Masjid-i-Sulaiman field in Iran is the world's fourth largest oil producer—its yield to date has been exceeded only by East Texas, Lagunas in Venezuela and the main field at Baku in the U.S.S.R. From a small number of wells, Masjid-i-Sulaiman has already produced more than 920 million barrels, and it is still flowing at a rate of 60,000 barrels a day. Its great well F7 produced 50 million barrels before it was abandoned. The next largest field in Iran, Haft Kel, has yielded 767 million barrels and is producing 191,000 barrels a day. The Kirkuk field in Iraq, the Burgan field in Kuwait and the Abqaiq in Saudi Arabia have probable oil reserves ranging from four to seven billion barrels each.

At Abqaiq, the oil comes from dolomite and oolite limestones. At the Bahrein field, production is from a younger oolitic limestone, and 2,000 feet below this stratum is a limestone deposit which is an important gas producer.

Exploration of the Middle East for oil is still in a relatively early stage. Development of the Iran, eastern Iraq and Bahrein fields was stimulated by the fact that surface folds which leaked asphalt and natural gas could readily be mapped. The fields in the rest of Iraq, Kuwait and Saudi Arabia have been geophysically outlined by the gravity meter and seismograph, and similar studies are in progress to uncover new fields in Iraq and Arabia. In Turkey, in addition to the fields developed at the north end of the Persian Gulf Basin, the small Adana basin near the Mediterranean is being explored. In most of Palestine, Israel, Lebanon, Trans-Jordan and western Syria there is ample folding, and several test wells are being drilled, but the lack of proper cover beds to seal in the oil allows these countries only minor possibilities. In Egypt three fields are producing at the edge of the Red Sea depression, and farther north rocks bordering the south Mediterranean shore are being explored. The south shore of Iran, which is an extension of Persian Gulf formations, should also be explored for oil deposits.

Saudi Arabia, with its great oil-bearing basin, will ultimately rank first in Middle East oil production. At present only a few Saudi Arabian coastal fields are developed; the whole interior to the south and southwest of the Persian Gulf needs to be explored. There may be fields on the north flank of the south Arabian coastal range and, more certainly, on the west flank of the Oman range. The second most promising area in the Middle East, controlled by Iraq Petroleum Company, includes Iraq and the southeastern coast of Arabia. The third is in Iran. There are great possibilities also in the little sheikdom of Kuwait and to a lesser extent in the area known as Neutral B.

The table at the bottom of the opposite page gives the number of developed oil fields in the Middle East, the number of wells producing and the daily production at the end of 1947.

	Iran	Iraq & Qatar	Kuwait	Saudi Arabia & Bahrein	Egypt	Turkey
Fields	7	7	1	6	5	2
Wells	71	11	5	117	166	0
Daily Barrels	472,000	91,100	62,000	333,000	35,260	

The Reserves

The oil reserve of the entire Middle East has been estimated by L. G. Weeks of the Standard Oil Company (New Jersey) to be 28.8 billion barrels. This figure is based on too few wells in certain fields; it must be taken as representing probable but not proved reserves. The petroleum geologist E. L. De Golyer estimated 16.5 billion barrels as proved in 1944. Adding 1.5 billion barrels for new discoveries since then would give a total of 18 billion barrels as the proved immediately available reserves of the Middle East. For comparison with other regions, however, the magazine *World Oil* estimate of proved reserves, 19.7 billion barrels, is used. The writer estimates the ultimate total oil reserves of the Middle East region as 100 billion barrels; two other authorities estimate 150 billion. As the chart shows, the Middle East's ultimate oil potential is greater than that of any other area except possibly the U.S.S.R.

Seventy per cent of the world's oil and gas resources is grouped in four regions: the Soviet Union, with ultimate possibilities of 160 billion barrels; the U.S. with 110 billion, of which 35 billion has already been taken from the ground; the Middle East with 100 billion, and the Caribbean with 60 billion. Weeks has estimated the world total to be 610 billion barrels and the all-time total of production up to January 1, 1948 as 51.8 billion, nine per cent of the total. The Middle East has yielded only 2.5 per cent of its potential reserves.

With oil in great demand, production in all four regions will rise steeply by the end of this year. The U.S. requirement alone will then be 5,780,000 barrels a day.

Russia's principal oil provinces are in the East Russian Basin west of the Urals, in the Caspian Sea province and in the Sakhalin-Kamchatka region. Its exploitation of its oil reserves, however, is 30 years behind that of the U.S. The Soviet Union presumably also controls the oil production of Rumania, Hungary and Poland, amounting to 121,000 barrels daily from pools in basin areas covering 130,000 square miles.

The main oil provinces of the U.S. are the Mid-Continent, California and Rocky Mountain. Recently much attention has been given to the exploration of deposits in the shallow waters of the continental shelf, particularly off the coast of California and the Texas-Louisiana Gulf Coast. Here important oil reserves may be uncovered. In the Caribbean region at the north end of South America the principal oil fields are in Venezuela, Colombia and Trinidad, with Venezuela representing perhaps 80 per cent of the possibilities.

The table on this page gives the number of producing wells at the end of 1947 and the total average daily production in each of the four regions.

	Middle East	Caribbean	United States	Soviet Union
Producing Wells	516	8,597	128,522	13,500
Daily Barrels	858,000	1,322,112	5,082,000	525,000

Ownership of Middle East Fields

The ownership of the principal reserve areas in the Middle East is divided approximately as follows: American companies—292,000 square miles; British-Dutch—233,000; French—37,500; Turkish—21,500; the independent C. S. Gulbenkian and his associates—7,900. In

addition there is a small area on the south shore of the Caspian Sea for which Soviet Russia has attempted to deal with the Iran Government. The American holdings are in the main indirectly owned in British limited companies, which operate under tax laws that are favorable to the accumulation of the large funds necessary for the development of the fields.

The company ownership is as follows: The Anglo-Iranian Oil Company Ltd., in which the British Government owns the majority of shares, holds the principal concession in western Iran, and a subsidiary has joint ownership with the Gulf Oil Corporation of the Kuwait concession.

The Iraq Petroleum Company Ltd. directly or indirectly holds the concessions on all of Iraq, half of Neutral A (a neutral area between Iraq and Saudi Arabia), all of Qatar, Oman, Trucial Oman, Hadhramaut, Syria, Israel, Palestine and Trans-Jordan. This company, in turn, represents several groups: Anglo-Iranian owns 23.75 per cent of its shares; Standard Oil (New Jersey) and Socony Vacuum jointly own another 23.75 per cent; Royal Dutch Shell and France own like amounts. The remaining five per cent is owned by the independent Gulbenkain.

The Arabian American Oil Company (Aramco) holds the concession for all of Saudi Arabia, and half of Neutral A. Aramco also owns half of the concession on Neutral B (an area of 1,100 square miles just south of Kuwait), the other half being held by American Independent Oil Company, in which Phillips Petroleum and other independents have an interest. Aramco is owned by Standard of California, The Texas Company, Standard of Jersey and Socony. The latter two recently negotiated for a 40 per cent interest in Aramco and have assisted in financing a pipeline across Arabia. Two subsidiaries of these four companies, one of which (Cal-Tex) is a Canadian firm, will control world marketing of Arabian oil. Standard of Jersey and Socony have also arranged to join Anglo-Iranian in the building of a big pipeline from Iran and in marketing its oil.

Thus, although American companies own a substantial share in the great Persian Gulf deposits, actual control is chiefly in Great Britain. In fact, these oil deposits represent one of the greatest quick assets of the British Empire.

World Markets

The plans for refining, transporting and marketing the oil of the Middle East are progressing fairly rapidly. Large refineries have been built at Abadan, Ras Tanura and Bahrein, all on the Persian Gulf, and at Haifa; smaller refineries are in operation at Kirkuk, Kermanshah and Suez. New refineries are planned in Alexandria and Tripoli. Abadan, processing 410,000 barrels daily, including 90,000 barrels of high octane gasoline, is the biggest refinery in the world. The total refining capacity of the Middle East plants is 775,000 barrels a day. The products are gasoline and fuel oil; no lubricating oil is made. Because the Middle East crudes are largely of the type that contains objectionable sulfur compounds which corrode pipes and tanks, special plants are required to remove the sulfur. This process, however, produces as a by-product the sulfuric acid needed in refining. So although refined products from these crudes are worth 20 cents less per barrel than those from East Texas crudes, the yield of sulfuric acid partly offsets the difference. In addition, such crudes frequently have a greater yield of high octane gasoline.

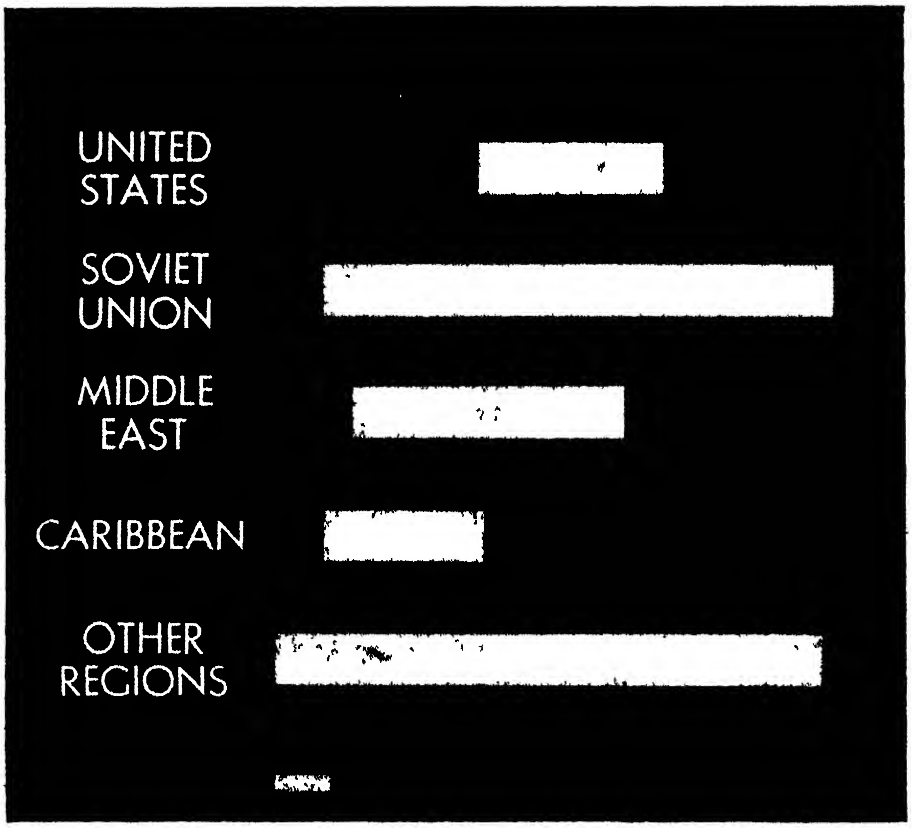
The oil of the Middle East is transported to world markets by pipeline and tanker. There are two desert pipelines in operation from the Iraq fields to Beirut and Haifa, each about 875 miles long. These 14-inch and 16-inch lines are being doubled to carry 300,000 barrels, and a 34-inch line for an additional 535,000 barrels daily is to be completed by 1951. They will supply refineries in Haifa, Tripoli and western Europe. A trans-Arabian line of 30 to 32 inches now under construction will pipe Arabian oil more than 1,000 miles to the Mediterranean near Haifa; it is scheduled to be completed by 1950 and will handle 330,000 barrels a day. These lines will shorten the tanker haul to Europe by 3,000 miles and avoid the tolls of the Suez Canal.

The natural markets for Middle East oil are western Europe, the North African coast, China, Japan, India, Australia and South Africa, which do not possess much oil of their own. (Indonesian oil is insufficient to supply southeastern Asia and Australia.) By 1951 Persian Gulf oil will come into more direct competition with American oil in the U. S. It is a competitor even now, before all the desert pipelines are completed.

The cost of producing Middle East oil at the wells is from 10 to 25 cents a barrel. It can now be sold profitably at the Persian Gulf for $1 a barrel. Even allowing a price of $1.25, plus an additional $1.25 for transport in company-owned tankers, it can be delivered in New York today for $2.50 per barrel, as against $3.02 for U. S. Mid-Continent oil. After the desert pipelines are completed, it will be possible to lay it down in New York via pipeline and tanker at a cost of $1.025 to $1.305 per barrel, including the tariff but not including a profit. U. S. Mid-Continent oil, now $2.60 at the wells, then will probably drop to $2. The U. S. and British navies have been purchasing fuel oil in the Persian Gulf at $1.05 per barrel: later this year the price will be raised to $1.48.

World Relationships

The availability of low-priced crude oil from the Middle East will enlarge world



OIL RESOURCES of various regions are compared in bar chart. Although Middle East has smaller proved reserves than the U.S. and a smaller undeveloped potential than the U.S.S.R., its smaller basinal area is richer.

markets for refined petroleum products and further stimulate the world-wide trend toward a liquid fuel economy. Oil development also means much to the countries of the Middle East. The governments of the oil-rich states of Iraq, Iran and Saudi Arabia receive royalties of 21 to 34 cents per barrel (these royalties account for 90 per cent of Saudi Arabia's income), and the other states will benefit from rentals for pipeline rights-of-way, from employment-providing refineries and from access to oil products at reasonable prices. If the ruling kings use their oil royalties wisely, they can do much to raise the living standard of the people in the Middle East. At the same time they will protect the tenure of the present governments. Among other things, the oil revenues could finance the harnessing of rivers for hydroelectric power and irrigation. The chief handicap to development of the land has been the large landowners. Aside from a sizable but only partially developed irrigation works in the Tigris-Euphrates Valley (which could care comfortably for many times the present population of Iraq), and a small-scale irrigation project in Saudi Arabia, little has been done in the oil regions to make the land capable of yielding food. The improvement of the land and the employment of natives by the oil companies will not only greatly better conditions for the present inhabitants but will allow for a greatly increased population.

Each of the major powers in the world has its own interest in the Middle East. The Soviet Union's desire seems to have been to regain eastern Turkey, to protect the Caspian Sea by obtaining control of northern Iran, to get an outlet to the Mediterranean at the Dardanelles and to obtain control, if possible, of a portion of Middle East oil because it would provide a quick, cheap oil source. The U.S.S.R. lacks both the capital and machinery to undertake development of its own oil resources and at the same time those of the Middle East. It would like to buy crudes from Middle East fields. Since pipelines to Russia are impractical, it would have to fetch the oil by tanker from the eastern Mediterranean.

The U.S., because of its highly developed liquid fuel economy, requires additional oil sources to supplement its own. Besides protecting the interest of its nationals in the great Persian Gulf deposits, it has undertaken jointly with Britain to prevent further Soviet access to the Mediterranean. The U.S., through its nationals, is best fitted technically and financially to assist in the development of Middle East oil. During World War II, it advanced a considerable amount of lend-lease to Saudi Arabia. It has no assurance, however, of holding a military base there to maintain its position.

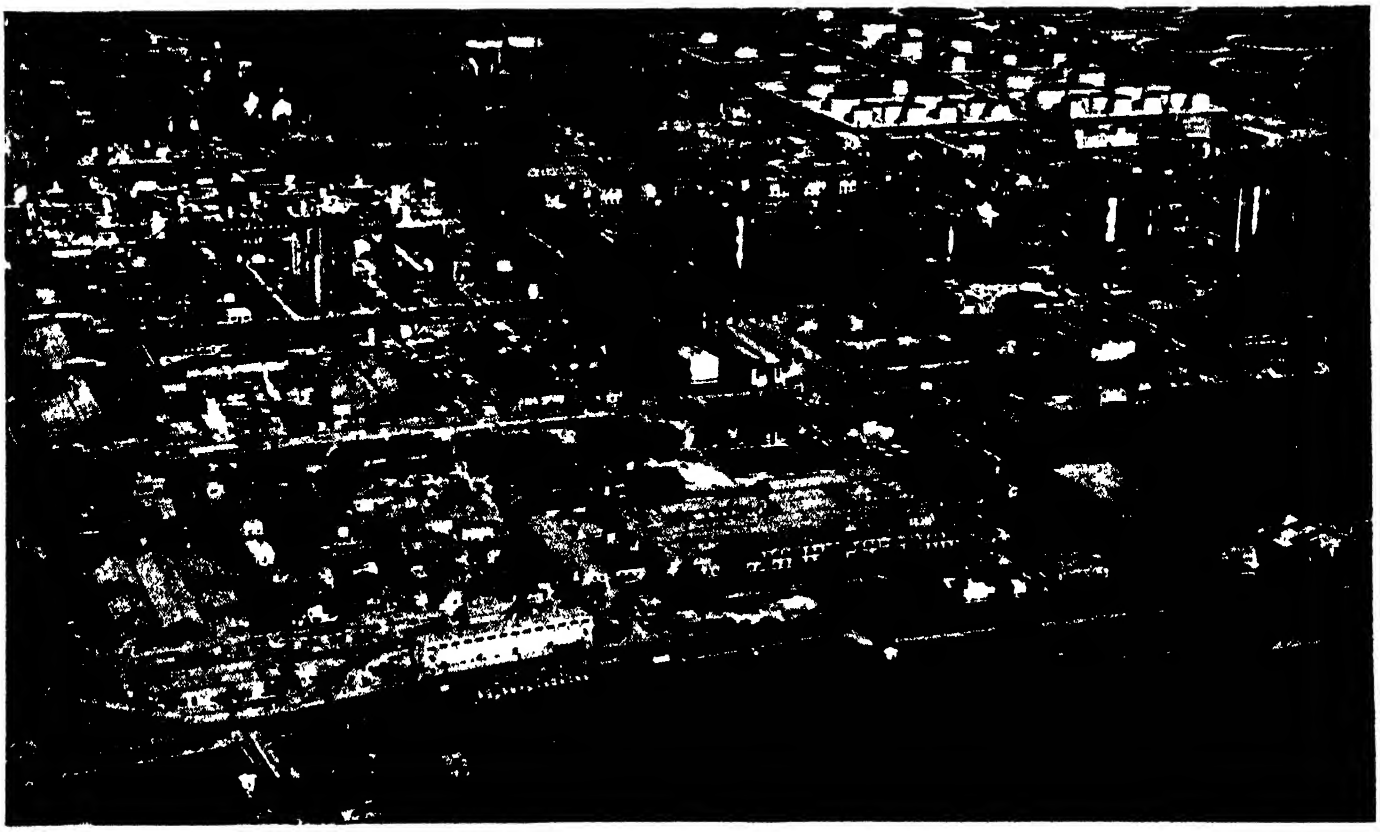
Britain's interest in the Middle East fields is to protect a major source of its wealth and credit from Soviet expansion; for this purpose it has established military bases in Trans-Jordan and Iraq and has done everything possible to satisfy Arab rulers. The Empire's recent loss of India, Burma, Ceylon, and probably now also of South Africa, as well as the loss of control over Egypt and Palestine, helps to explain its effort to maintain its Middle East position at any cost.

France has a direct interest in Iraq—her only important oil source. As ruler of the North African colonies of Algeria and Morocco, both Arab, she wishes to keep at peace with the Arab world.

As for the new state of Israel, it too is anxious to achieve peace with the Arab world. Far from being a thorn to Arabdom, Israel's modern and democratic standards can be a catalyst in the renaissance of the feudal Arab states.

Indeed, it seems clear that to maintain access to Middle East oil it is essential that the Western powers avoid war. In case of a general conflict, it would be necessary to fill the completed wells with concrete to save the Middle East fields from fire and destruction, for no defense save retaliatory bombing is possible. In the last war no enemy power was within easy bombing range of the Middle East oil fields, but long-range bombers have changed this. Except for possible stockpiling, the Western powers can depend on these fields for peacetime use only.

F. Julius Fohs is a petroleum geologist and an independent oil operator of Houston, Texas.



REFINERY AT ABADAN, at the head of the Persian Gulf, is the largest in the world. Abadan processes 410,000 barrels of crude a day, producing, among other things, 90,000 barrels of high octane gasoline. There are also several other refineries on the Persian Gulf and on the Mediterranean, the latter fed by the desert pipeline.

RADIO WAVES AND MATTER

The highest radio frequencies, explored during the war for their utility in radar, have recently illuminated some dim recesses in the world of atoms and molecules

by Harry M. Davis

I hear beyond the range of sound,
I see beyond the range of sight,
New earths and skies and seas around,
And in my day the sun doth pale his light.
—Henry David Thoreau
Inspiration

RADAR, the warborn invention that sees in the dark, that pierces clouds and fog and detects tiny targets beyond the range of human sight and hearing, has inspired in many scientists just such a sense of unfolding discovery and of elation as Thoreau expressed in these prophetic lines. Radar is best known as a military weapon and a marvelous aid to navigation, but more fundamentally it has given man a new tool, almost a new sense, with which to explore the universe. With radar he has already reached out to the moon, and with radar's microwaves physicists are now exploring the depths of the atom. Through microwaves physics has entered a new region of the electromagnetic spectrum that illuminates the innermost structure of matter more brilliantly than light itself.

The discovery of the wonderful properties of microwaves reversed the usual order of development in science; it derived from technology, but more and more its fruits are being found in the realm of pure knowledge.

Mysterious Interference

The wartime race among the radar researchers of the opposing powers was in large measure a race toward the shorter and shorter wavelengths—from short waves to microwaves. Each time the frequency frontier was moved to a shorter wave band it opened a new region where, it was hoped, the enemy could neither intercept nor jam the radar beams. Of equal or greater importance, it meant getting better definition and accuracy in radar images. As planes were equipped successively with "S-band" radar (10 centimeters wavelength) and then with "X-band" (3 centimeters), targets such as Bremen and Berlin sharpened up from vague blurs on the oscilloscope to clearly defined patterns of main thoroughfares, clusters of buildings, rivers, bridges, parks and piers.

Toward the end of the war, Allied radar researchers reached beyond the X-band into a new realm below 3 centimeters, known in the secret listing as the K-band. Extrapolating from previous experience, this should have given better radar than ever. But when the first sets got into the field, mysterious troubles developed. The sets were not getting the distance they were designed for. And they were erratic. On some days the reception was remarkably good. On other days, the radars seemed to go half blind. Soon it was observed that the K-band radars performed at their worst when the air was damp. A muggy day could play havoc with transmission.

The military problem of finding a solution for this difficulty was assigned to physicists at the Radiation Laboratory of Columbia University, which was responsible for developing K-band tubes. (The cavity magnetron, which made high-powered transmission of microwaves possible, had been developed by British scientists at Birmingham University, and the X-band tubes had been designed by the Radiation Laboratory at the Massachusetts Institute of Technology.) The Columbia physicists recalled a prediction that John H. Van Vleck of Harvard had made on a theoretical basis, and they quickly confirmed it by experiment. Van Vleck had predicted that at certain wavelengths microwaves would be absorbed by water vapor. The experimenters found that this was indeed the case: on a humid day in the tropics a radar signal of the predicted wavelength, if beamed at a target only three miles away, would lose 94 per cent of its energy by water absorption alone. This effect was above and beyond the normal absorption due to droplets of rain.

MICROWAVE EXPERIMENTS performed by Willis Lamb and Robert Retherford at Columbia University have employed this apparatus. At left and right, fitted with cooling fins, are poles of magnet. Radio frequency is passed across beam of hydrogen atoms in chamber between poles *(page 20)*.

The explanation of this phenomenon lies in the field of quantum theory. According to this theory, each kind of atom or molecule possesses a number of possible states of energy. It occupies only one state at a time, and each state is separated from the one next above or below by a

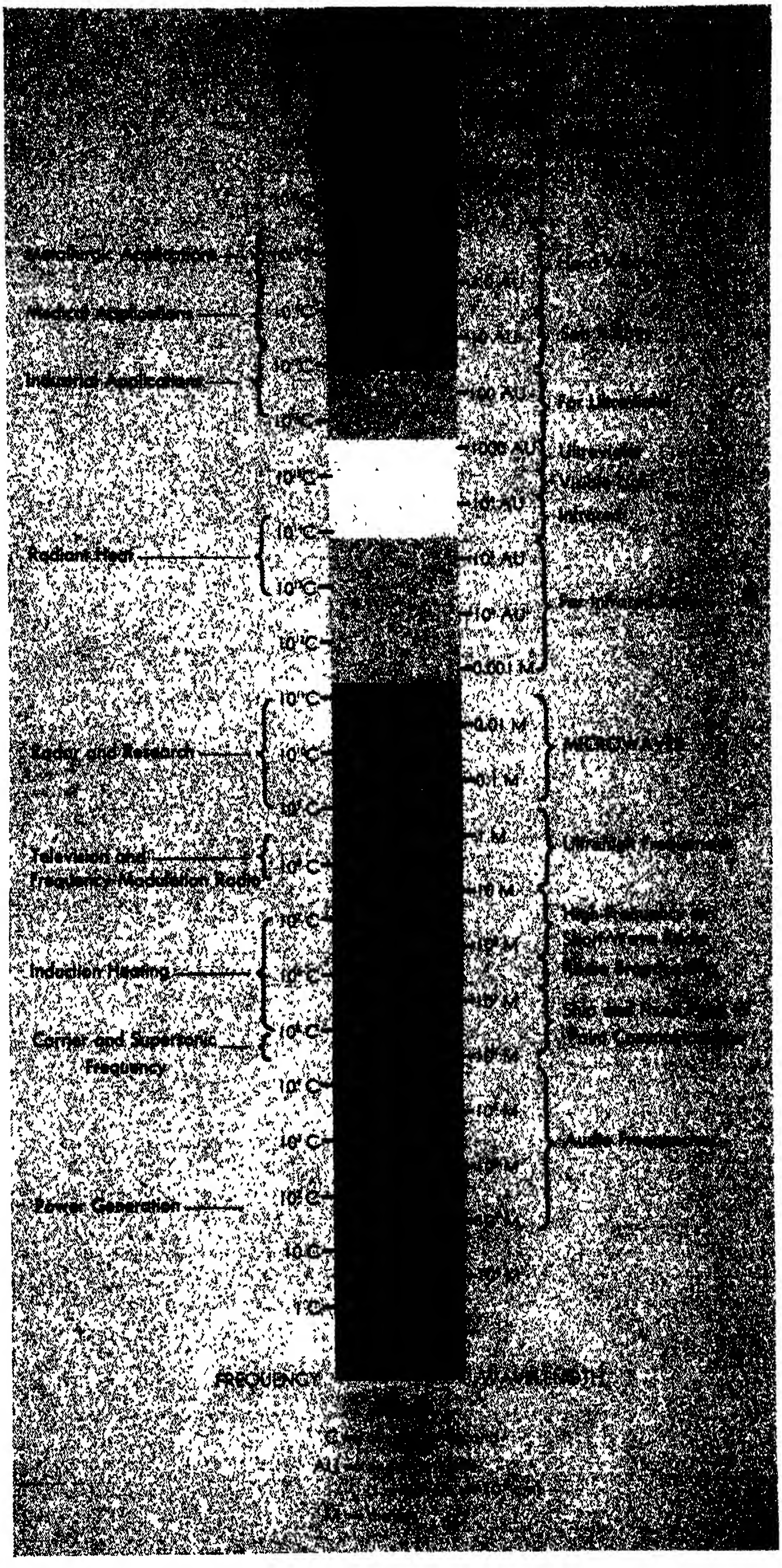
certain difference of energy, called a quantum. To go to the next higher energy state, the atom or molecule must absorb a quantum; to go to the next lower one it must shed a quantum. A molecule will accept only the quantum of energy that can raise it to a higher energy state; by the same token, a wave of energy encountering a molecule must carry the right quantum or it will produce no effect. And the quanta of energy carried by the wave depend, in turn, on its wavelength.

Max Planck's and Albert Einstein's famous statement of the quantum theory says that each quantum of energy carried by any given radiation (such as a specific wavelength of yellow light) is directly proportional to the radiation's frequency, *i. e.*, the number of waves per second. Consequently, whether a molecule will absorb a radiation depends upon the radiation's frequency or wavelength. A wave that carries the wrong quanta will sail right by; the molecule is transparent to it. But when the right wavelength comes along, the molecule grabs it and is hoisted to a higher energy level. The molecule is said to be resonant to this wavelength, and the phenomenon of energy-capture is known as resonance absorption. The quantum thus absorbed is subtracted from the energy of the radiation. If enough resonant molecules get in the way of a beam, whether of light or radio waves, its energy may be completely absorbed and the beam is blocked.

In the case of the K-band radar, as it happened, the middle of the wave band accidentally fell squarely on a strong absorption wavelength for water—1.33 centimeters. So the invisible molecules of water vapor in the air effectively absorbed and blocked the radar signals. The remedy was simple: a shift of the radar wavelength away from the water molecules' resonance point.

The Columbia study that developed from this military problem underlined a possibility of which a few physicists had become aware: that the powerful new microwave equipment developed by radar could be used to tune in on the inner secrets of the molecule, the atom and even the ultimately small particles of the atomic nucleus. Almost everything previously known about the structure of atoms had come from study of their visible spectra, that is, from splitting the light emitted by heated atoms into its component lines or wavelengths on the color spectrum. By means of microwaves units of matter can be analyzed in a somewhat similar but frequently more accurate way, and many fundamental new facts have already been learned about the shape, size and arrangement of molecules, the orbits of electrons around atomic nuclei and the spin of protons and neutrons within the nucleus.

At the same time, the discovery of the properties of microwaves has dramatized the unity of the entire electromagnetic



THE ELECTROMAGNETIC SPECTRUM dramatizes the relatively close kinship between the highest radio frequencies and light. Most radio spectroscopy utilizes the microwave region next to the infrared. Frequency of radiation is indicated at left of this vertical spectrum, wavelength at right.

spectrum, for these very short radio waves have been found to perform in many ways much like light waves.

The Broadened Spectrum

Man first observed the spectrum where it was most evident: in the rainbow of visible colors from red to violet. But from the viewpoint of modern physics, visible light is only one octave in the vast keyboard of electromagnetic radiation. It is now known that radiation exists in nature over a great range of frequencies, and that the frequency of oscillation (or, looked at another way, the wavelength) is the only physical difference among gamma rays, X-rays, ultraviolet rays, visible light, infrared or heat rays and radio waves. In each case the frequency multiplied by the wavelength is equal to *c*, the velocity of light: 30 billion centimeters per second. That part of the spectrum which we call light is visible because the molecules of visual purple, or rhodopsin, in our retinas are chemically attuned to that particular range of wavelengths.

The shortest waves of the visible spectrum, those of violet light, are approximately .00004 centimeters in wavelength. The longest visible waves, at the red end of the spectrum, are about .00008 centimeters. From them we must take a leap by a ratio of a billion to get to the radio wavelengths in the regular broadcast band, which are measured in hundreds of meters.

Even before the invention of radio, James Clerk Maxwell, the gifted 19th-century Scottish mathematical physicist, had shown that its electromagnetic waves were of the same nature as light, but the kinship long seemed more academic than practical. Recent radio and radar developments, however, have whittled down the gap. Most modern radar equipment operates on wavelengths measured in centimeters rather than meters, and some laboratory oscillators have been tuned down into the millimeter region. At these lengths the waves behave as much like light as like ordinary radio. They are transmitted and received not by the conventional wire radio antenna but by a parabolic reflector resembling a searchlight, or by a metallic "lens." Except under very special atmospheric conditions, the ultra-short waves refuse to bend around the curved surface of the earth, as do long radio waves, but proceed in straight lines like a beam of light (a factor which poses a serious engineering problem for short-wave television). Within a microwave set, the waves will not cling to wires but must be channeled inside hollow waveguides resembling square pipes, which physicists call "plumbing."

It is not surprising, therefore, to find that some material substances react with microwaves as other substances react with the visible portion of the spectrum. Just as grass and leaves absorb red light and reject (and thereby reflect) green, one might expect the gases of the air to respond in different ways to the various invisible "colors" of the microwave radio spectrum. Every substance has its favorite energy levels, which are in turn resonant to certain wavelengths. Thus while air is transparent to both the long waves of ordinary radio and the very short waves of visible light, it does not necessarily follow that air will be equally indifferent to waves in the microwave band between light and ordinary radio. As a matter of fact, it is not in general transparent to them. Molecules of oxygen, like those of water vapor, exhibit definite absorption in the microwave region. And many other gases, not found in the air but available in the laboratory, show the same property.

Microwaves and Molecules

Clerk Maxwell, besides laying the groundwork for the electromagnetic theory of radio and light, also did important work in what was then the new kinetic theory of gases—a theory which correctly supposed that the behavior of a gas in such matters as temperature and pressure was the statistical result of the random movements of enormous numbers of individual molecules. He also introduced the concept that the laws of gases, based on anarchy and statistics, might be evaded if some tiny demon were available that could open and close gates to sort out the faster and slower molecules. "Maxwell's demon" has been a useful fancy in the teaching of thermodynamics and allied branches of physics.

No such demon exists. Yet microwaves offer something akin to it, since they virtually take control of individual molecules and regiment them as no other force can. They can be used to control not only such gross, statistical qualities as pressure and temperature but many subtle properties of gas molecules as well. They may affect the molecules' rotation and orientation, and may even stretch the links between the atoms that constitute the molecule. In at least one case, ammonia, radio waves can literally turn the molecule inside out.

In the case of the absorption of microwaves by water vapor, the energy states of the water molecule have to do with the rotation of the molecule. (Incidentally, the scientist's increasing knowledge of molecular structure is graphically illustrated by a revision of the familiar chemical symbol for water, which nowadays is usually written by chemists not H_2O but HOH, indicating that the oxygen atom is in the middle, with the two hydrogen atoms branching off at an angle on either side.) The molecule as a whole rotates, and in its vapor form it has room to spin freely like a top. It can spin in a number of different ways, each representing one of its possible energy levels. It can jump to a higher level only by receiving the proper quantum of energy. One of these quanta, as previously pointed out, corresponds to the K-band radiation of 1.33 centimeters wavelength, but the HOH molecule also has a series of other absorption levels at wavelengths below one millimeter. (Thus there is little future for radar or radio communication in the region below one millimeter—except in the driest desert climate.)

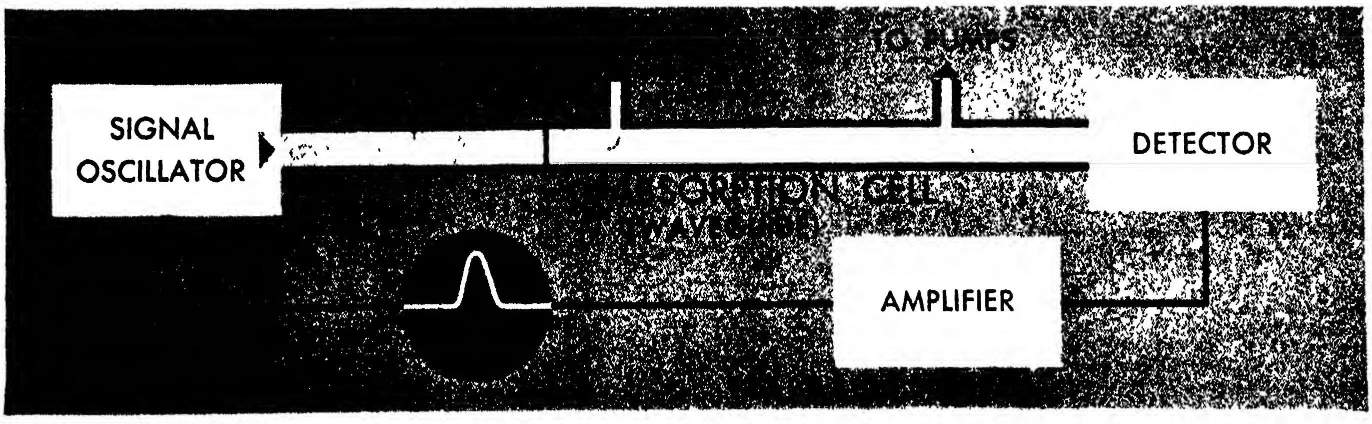
Ammonia, NH_3, is one of the molecules that has been most carefully studied by microwave resonances. Even before radar, in 1934, C. E. Cleeton and N. H. Williams at the University of Michigan employed an early low-power form of centimeter-wavelength magnetron and sent its radiation through a rubber balloon filled with ammonia gas. They found that the balloon greedily absorbed radio waves at 1.25 centimeters, or at a frequency of 24,000 megacycles (24 billion cycles) per second. More recently, with the powerful new radar K-band oscillators and accurate receivers, ammonia's behavior has been observed as minutely as that of a child in the famous Yale clinic of Arnold Gesell. Work on its radio spectrum has been carried out by B. Bleaney of England's Oxford University; by C. H. Townes, originally at the Bell Telephone Laboratories and now at Columbia; by William E. Good, D. K. Coles, and T. W. Dakin at the Westinghouse Research Laboratories, and by other groups. The work is being extended to other gases. Some of the results are truly remarkable. They begin to give a vivid physical meaning to the indirectly formed theories of molecular structure.

From the weights of chemicals that combine to make it, chemists have long known that the formula of ammonia is three atoms of hydrogen and one of nitrogen. But what about their arrangement? From various kinds of evidence, it is understood that the three hydrogen atoms form a triangle, with the nitrogen atom in another plane like the apex of a pyramid. If you think of the hydrogen triangle as being in the plane of this page, then the nitrogen atom could be either above or below. The microwave research now shows that it can occupy either position alternately, and the resonant wavelength of 1.25 centimeters is just what is required to keep the N atom oscillating. The physicists describe the effect as "tunneling" and speak of the 1.25 centimeter resonance as due to the "inside out" or "inversion" spectrum of ammonia gas.

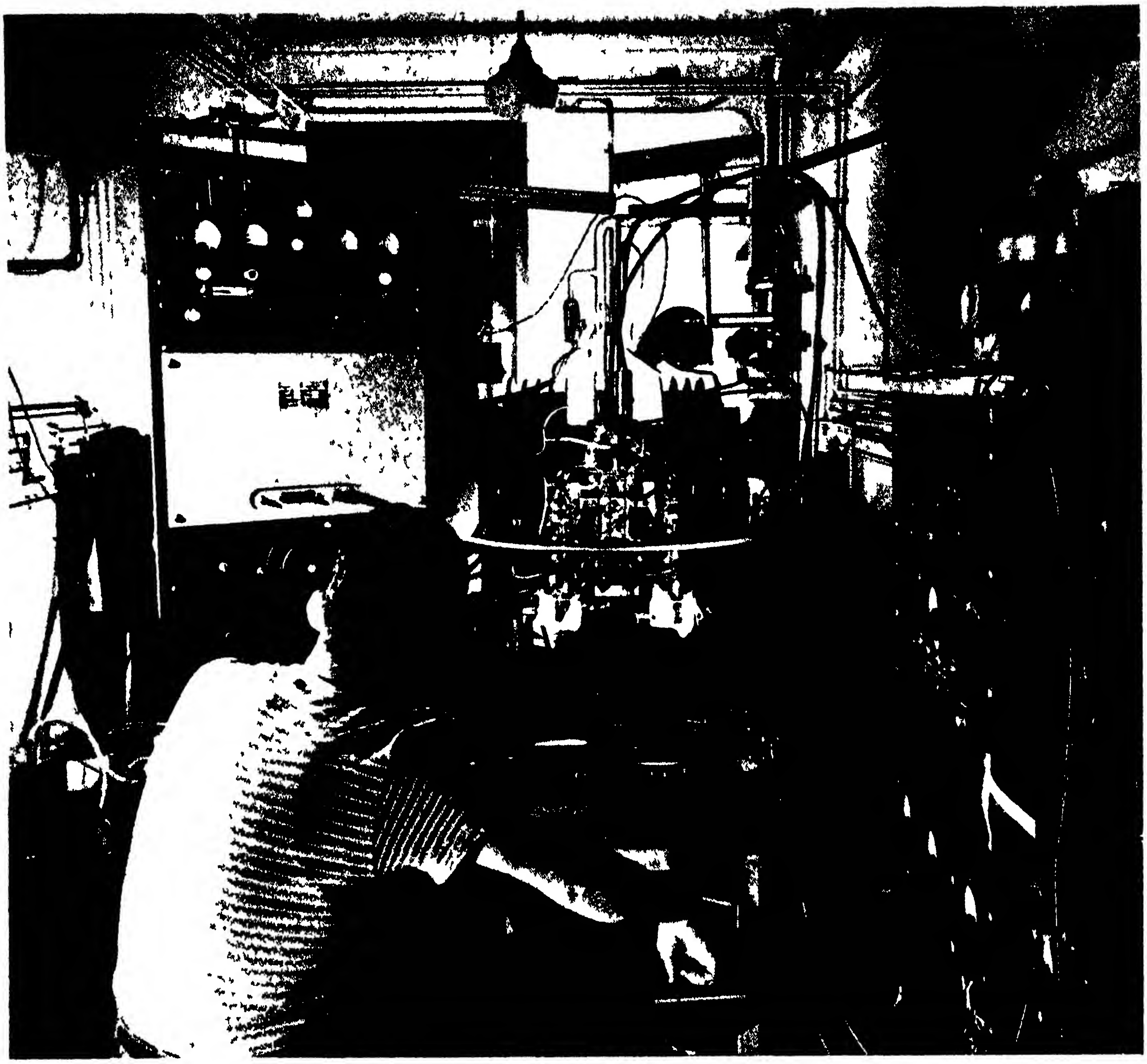
There is more to it, of course. Besides turning itself inside out, the ammonia molecule is also vibrating and rotating. In addition, since no molecule can be isolated by itself, the study of ammonia gas involves collisions among the molecules, which transfer energy back and forth. All this can be analyzed by its effects on the inversion resonance.

At atmospheric pressure, when collisions among the molecules are frequent, the resonance band is broad, extending from about 1.1 to 1.5 centimeters, and

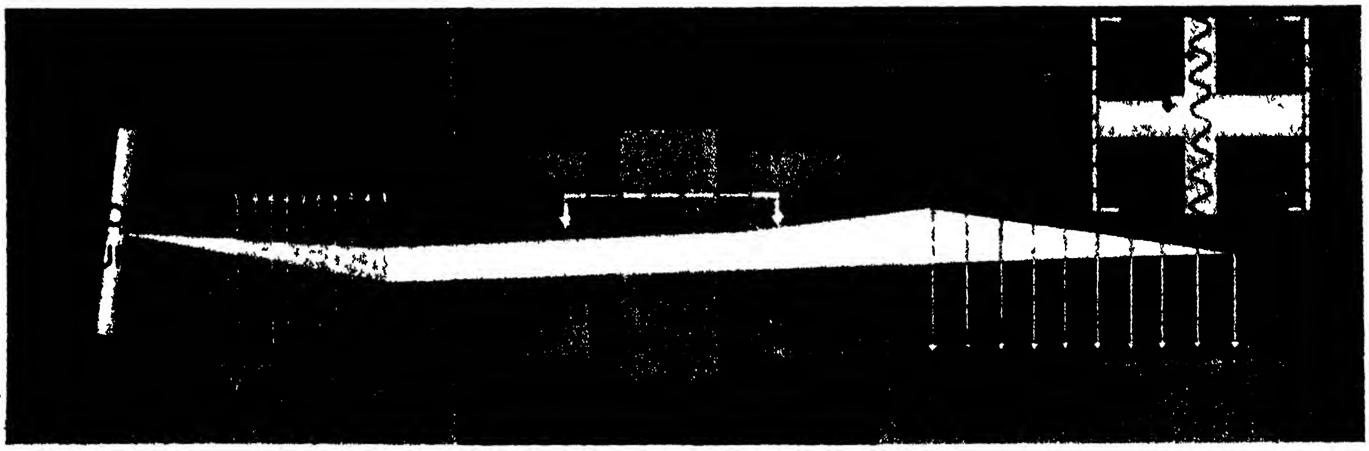
MICROWAVE SPECTROGRAPH of C. H. Townes at Columbia is used to analyze properties of gas molecules and their constituent atoms. Gas is admitted to long waveguides (*rectangular pipes running past Physicist Townes' left hand*) from around flask at lower right. Wavelength is indicated by oscilloscope at upper left.



SIMPLIFIED DIAGRAM of the apparatus in the photograph above shows its principal parts. Gas to be analyzed by microwaves is admitted to a sealed part of the waveguide running from microwave oscillator to detector. Absorption of microwaves by molecules can then be calculated with help of image on oscilloscope.



LAMB AND RETHERFORD apparatus, here run by Retherford, fires a beam of hydrogen atoms between poles of magnet in background. When microwaves crossing beam are tuned, atoms of certain energy state are eliminated. Diminution of these atoms is measured by galvanometer and shown by spot of light on scale at left.



BEAM of hydrogen atoms in lowest energy state (*top of drawing on opposite page*) is produced at left. Passing through electron beam, atoms are raised to a higher state (*middle of same drawing*). Only these atoms knock electrons from tungsten plate. When microwaves topple atoms to third state, galvanometer voltage drops.

higher pressure can broaden it still more. Radio men would say that, as a receiver, a container of high-pressure ammonia has poor selectivity. But as the pressure is lowered, and the molecules begin to act more as free individuals, the absorption line sharpens up. It also exhibits a "fine structure"; the absorption line is made up of some 30 distinguishable constituent lines. These have been identified with the various states of rotational energy that the NH_3 molecule can occupy. As it spins faster, its pyramid of four atoms is strained and stretched by centrifugal force, and the amount of radio energy needed to turn it inside out is altered. In a container of gas, the billions upon billions of molecules will include large numbers at each possible rotational speed level, each absorbing energy on its preferred wavelength. Thus when a K-band radar tube has its tuning swept automatically through this region of frequencies, the receiver will display a cluster of adjacent absorption lines.

This kind of test is being applied to all sorts of chemical compounds. Specimens of gases and liquids in tubes and pipes are exposed to super high-frequency microwaves to find their characteristic resonances. By this method more and more is being learned about the qualities of the molecules' structure—the distance between the atoms, the way they are arranged and the electric and magnetic forces among them. Moreover, since each molecule has its own individual pattern of resonant wavelengths, as personal as a fingerprint, microwave tuning offers a new method of identifying chemicals. Chemical analysis, which has been aided greatly by optical spectroscopy and mass spectrography, now is likely to find another handy tool, at least for some compounds, in microwave spectroscopy. Further possibilities beckon. Already the Harvard physical chemist E. Bright Wilson, Jr., is using the molecular information revealed by microwaves to seek new ways of synthesizing chemical compounds.

Again, the absorption technique might be a useful tool for radio itself. In the technical language of communication, anything that absorbs at a particular wavelength may be called a filter. The filters hitherto used in radio and telephony are arrangements of coils, condensers and resistances, often accompanied by quartz crystals. The possibility now emerges of gaseous filters in the microwave region which, like the colored lens filters of photography, would directly absorb unwanted wavelengths while letting through those needed for purposes of communication.

The Hydrogen Atom

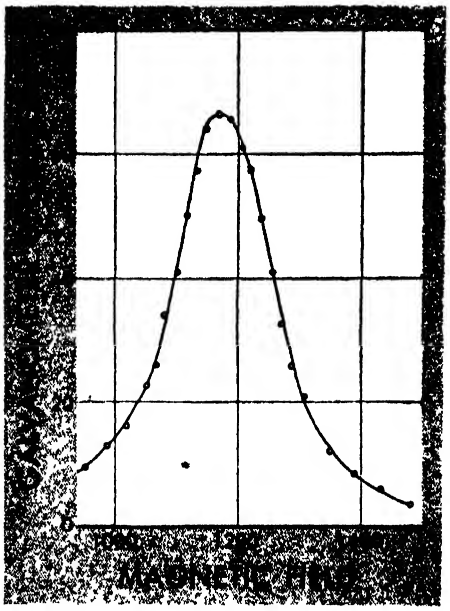
The most intensively studied of all atoms has been that of hydrogen. Its optical spectrum has been explored for decades. The reason is that hydrogen is the simplest atom: one electron rotates around a nucleus consisting of a single proton. Science could not hope to make any sense out of the spectra of heavier and more complicated atoms until it could unravel the meaning of the pattern of bright lines of various colors emitted by "excited" atoms of hydrogen. Here were found the celebrated Balmer and Lyman series of spectral lines, in which the sets of frequencies in the various energy states of the atom were found to be related to one another by a surprisingly simple mathematical formula.

Niels Bohr's historic contribution to understanding of the atom was that he succeeded in applying the quantum concept to the spectrum of hydrogen, showing how its succession of visible wavelengths corresponded to parcels of energy emitted as hydrogen's lone electron dropped from one orbit to another. From the springboard of that theory scientists went on to attack the spectra of the larger atoms and their combinations into molecules. Thus a huge edifice of both physics and chemistry has been built upon the understanding of hydrogen's visible color spectrum. Every advance in quantum mechanics and relativistic electrodynamics—notably the theories of P. A. M Dirac, the 46-year-old British mathematician who is now at the Institute for Advanced Study at Princeton—had to survive the test of its ability to explain the hydrogen spectrum.

There are limits, however, to the accuracy of measurement of the visible spectrum. Despite great technical improvements in optical spectroscopy, some of the lines are so close together that it is impossible to resolve them—that is, to learn whether one or several pairs of energy levels are involved in some phase of the movements of the hydrogen electron. Willis Lamb of Columbia University decided to tackle this ambiguity by means of the invisible "light" of microwaves. His approach was eminently reasonable. If you want to measure the amount of a liquid accurately, it is logical to use a small unit—a pipette, say, rather than a gallon jug. Similarly, a quantum of red light carries more than 50,000 times as much energy as an X-band microwave. Thus microwaves, representing smaller energy units, should permit finer measurements.

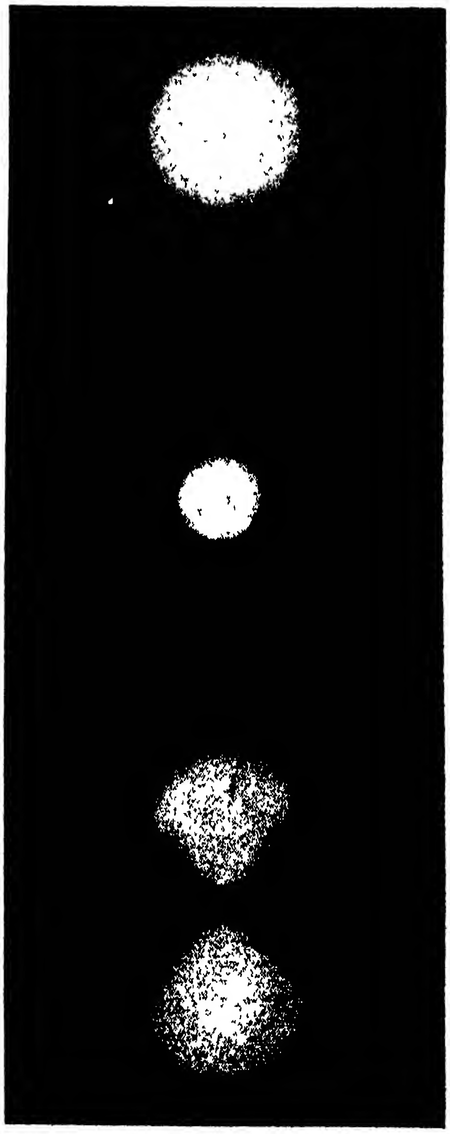
Lamb was in a good position to test hydrogen in this new region of the spectrum. He was associated with the group led by I. I. Rabi, winner of the Nobel Prize for his pioneering work in the radiofrequency spectrum of molecular beams. Lamb was also a member of Columbia's Radiation Laboratory, which had led in K-band radar and is still engaged in developing microwave oscillating tubes under a postwar contract with the Army Signal Corps.

In an ingeniously designed experiment, Lamb and Robert C. Retherford



CURVE of data from Lamb and Retherford experiment is analogue of absorption line in light spectrum.

STATES of atoms in hydrogen beam (*diagram on opposite page*) change the configurations of electron cloud.



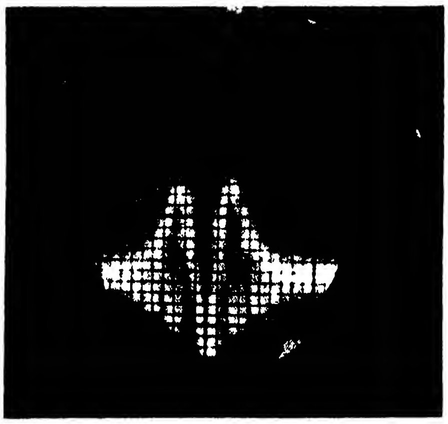
fired hydrogen atoms between the poles of a powerful magnet towards a distant detector. The apparatus was so set up that only the atoms which had their electrons in a certain orbit would register on the detector. A microwave oscillator was then arranged to shoot its parcels of energy across the hydrogen beam. When the microwaves carried the right quantum of energy, they toppled the electron orbit from one level to another and the hydrogen atoms so altered were not recorded on the target. By tuning the microwave oscillator and watching the detector, the experimenters could observe just what quantum of energy was required to change the electron's orbit. The answer, in this experiment, came out at a wavelength of 3.03 centimeters instead of the 2.74 centimeters expected from the celebrated Dirac theory. So refined is the modern theory of the atom that this discrepancy was enough to throw the whole world of physics into its most intensive error-hunt of a decade.

Since the experimental evidence was unimpeachable, everybody looked with new skepticism upon the long-established theories. The bigwigs of theoretical physics began to turn relativity and quantum electrodynamics inside out to find the flaw. H. A. Bethe of Cornell, who had previously gained distinction by explaining how the sun shines by the nuclear transformation of hydrogen into helium, suggested an exciting answer to the new hydrogen dilemma. He showed that the existing theories could be preserved in the face of the discrepancy by defining the mass of such a particle as an electron in a fundamentally new way. Then, at a meeting of the American Physical Society in New York last January, the brilliant 30-year-old Harvard mathematical physicist Julian Schwinger wove this into an elegant and widely applauded restatement of quantum electrodynamics.

The philosophical significance of Schwinger's modification is not for this article to explain; nor is it too well understood as yet by the physicists themselves. It exemplifies, however, the far-reaching effect of a new experimental technique which permits a most precise testing of the details of atomic theory. Lamb and Retherford are still hard at work on further refinements of their search into hydrogen's microwave spectrum, and they may yet give the theorists more trouble and, in consequence, more enlightenment.

Microwaves and the Nucleus

In one sense, all this study of molecules and whole atoms is merely investigating the fringes of the problem. In atomic physics it is the power-packed nucleus that now holds the center of the stage. And perhaps the most exciting explorations made by the microwave apparatus of [illegible] have been those in the nucleus. As a matter of fact, all the work done on molecules and atoms also involves nuclear effects, even if they are indirect. The nuclear effects can be segregated from those which belong to the outer structure of the atom by comparing the behavior of different isotopes of the same atom. For instance, in the Columbia experiments, Lamb and Retherford plan to put deuterium through the same paces as hydrogen. Deuterium, the heavy isotope of hydrogen, differs from ordinary hydrogen only by the presence of an added neutron in its nucleus; it still has only a single satellite electron. Thus if deuterium's electron resonates to microwaves in a different way from the electron of ordinary hydrogen, it must be the larger nucleus which produces the variant effect. In the case of water, the K-band absorption line is definitely shifted if deuterium is used instead of hydrogen, making heavy water. Experiments have been made with ammonia into which heavy nitrogen, of atomic weight 15 instead of 14, is compounded. In each of these cases the experimenter literally tunes in to a nuclear effect, since the only difference between the heavy and the light isotope is



PEAK on oscilloscope indicated characteristic resonance of proton in the work of Bloch and associates

the extra neutron in its nucleus. Certain results of this work indicate that some nuclei are spherical, and others are shaped like a cigar or a pancake.

What is observed in these experiments with isotopes is the effect of nuclear mass and shape on the atom or the molecule. Once these effects are fully explored, microwave spectroscopy may serve as a quick means of measuring how much of what kind of isotope is present in a naturally or artificially mixed sample of an element. Hitherto the easily traced radioactive isotopes have been favored by biologists and chemists in their "tagged atom" research. The possibility of identifying isotopes by their microwave spectra should kindle new interest in the stable isotopes, which have advantages from the viewpoint of safety for the experimenter.

Beyond these somewhat indirect dealings with the nucleus, within the past two years an almost incredibly refined procedure has been developed for by-passing the electronic shells of atoms and resonating directly with the nuclei, making them literally dance in rhythm with a radio wave. This method depends on the fact, first surmised in 1924 on the basis of some peculiarities in optical spectra, that most (but not all) nuclei have a characteristic spin—a spin which is separate from that of the molecule or atom as a whole. In a way, this provides a further analogy between the atom and the solar system. Electrons revolve around the nucleus as the earth and other planets revolve around the sun. But the sun itself also spins on its axis. Just so, the nucleus spins on its axis. Again, the spinning earth and sun are magnets, with north and south poles. So, too, is the spinning nucleus.

In the world of the atom, these spins cause an interaction between the magnetic fields of the satellite electrons and the field of the central nucleus. These interactions show up in the hyperfine structure of the lines in the visible spectrum. But the distance between these hyperfine visual lines is so small that it is difficult to measure with any accuracy. And so here is another opportunity to employ the more delicate measurements of radio waves.

If the magnetized nucleus reacts to the magnetic field of moving electrons, why should it not react also to the forces of a powerful external magnet? Two groups of experimenters—at Harvard and at Stanford—saw this as the basis for a new kind of resonance experiment. The forces applied to the substance under study were two: 1) a steady magnetic field, which could be varied in strength; 2) an oscillating magnetic field or radio wave, which could be varied in frequency. The idea was that the steady magnet would cause the tiny nuclear magnets to line up with the applied magnetic forces, like minuscule compass needles. Then the oscillating force of the radio wave would give some of the nuclei the impetus to flip over in the opposite direction, like compass needles pointing the wrong way. The frequencies which accomplish this are in the realm of short-wave radio.

As the experiment was set up at Harvard by E. M. Purcell, H. C. Torrey, and R. C. Pound, the innate magnetism of the proton was studied by using such hydrogen-rich substances as a drop of water or a blob of paraffin. The sample, in a small glass tube, was surrounded by a coil of wire carrying the radio-frequency current, which in turn was placed between the poles of a powerful magnet. As the magnet strength or the radio wavelength was changed, a sharply defined point was found at which the coil of wire showed an increase of electrical resistance. The conclusion was that at this particular combination of magnetic field and wavelength the test substance was able to absorb energy. That this was not a molecular phenomenon was made clear by the fact that resonance took place at the same

wavelength regardless of whether the material tested was liquid water, ice, paraffin, or some other substance—so long as it contained hydrogen.

An interesting variation was independently worked out at Stanford by Felix Bloch, William W. Hansen and Martin Packard. Bloch, who has conducted most of this research, had served during the war at both the Los Alamos atomic-bomb laboratory and at the Radio Research Laboratory at Harvard, home of countermeasures against enemy radar.

He worked on the theory that a spinning proton, when its essential magnetism is subjected to both an outside magnetic field and a radio wave, will precess (wobble) like a top, so that its axis at any moment is not exactly in line with the magnetic field created by the outside magnet but is at an angle to it. This, he reasoned, should cause the spinning particle to give out radio waves at right angles to those it received from outside. Exactly that happened. When a radio wave was sent into a proton-rich material from one direction, an answering signal came out in another direction and was picked up on a radio receiver tuned, in one instance, to 42.5 megacycles. As the receiver, not unlike those used to intercept enemy radar signals, was swept through the frequency band, it showed a sharply tuned resonance peak on a radarlike oscilloscope.

By a different although somewhat related method, a research group at Stanford has measured a magnetic moment for the fundamental uncharged particle, the neutron. The unexpected magnetic property of the neutron is one of the important recent clues to the mysterious inner nature of all matter. It is easy to see why a spinning electrified particle should have magnetism, for the principle is similar to that of any electromagnet or electric motor. But the existence of magnetism in the neutron has posed a new problem. It indicates that this particle, which was named neutron because it was supposed to be electrically neutral, actually belies its name and, like a miniature atom in itself, must have some complex distribution of positive and negative charge.

The wonderful thing about these nuclear resonance experiments is their fantastic precision. In one instance described by Purcell, the frequency involved, 29.500 kilocycles, was measured with an accuracy within one kilocycle.

The accurate value just mentioned was found for protons in liquid water. When the water was frozen, however, the resonance peak became flatter and from 20 to 50 times as broad. The explanation is that ice is a crystal in which adjacent protons occupy fixed positions and are able to interfere with each other's magnetism. In warm water, on the other hand, the rapid random thermal movement of the molecules causes these effects to average out during the brief duration of a single radio wave, so that the intrinsic magnetism of the individual protons stands out sharp and clear.

This kind of effect is now being used, not only by physicists but by physical chemists, to get a clearer picture than ever before possible of the shape and structure of molecules and their relative arrangements in solids and liquids. Thus, after by-passing the molecule and the atom to get at the nucleus, it is now possible to use the inner magnetic workings of nuclei to get a better definition of the larger, but still invisible, molecular aggregations of matter.

Microwaves and Time

Microwaves may have another important scientific use quite aside from those in the laboratory. In all the experiments described in this article the quantity measured is frequency—the number of electrical oscillations per second. Stated in another way, the quantity measured is time—the duration of one oscillation. The measurement is extremely accurate, already approaching one part in a million. And it can readily be compared with conventional timepieces; ultimately the oscillations of microwaves can be tied in with an electric clock running on 60-cycle alternating current.

These clocks at present are regulated by astronomical observation of the earth's daily rotation and its movement around the sun. A clock regulated by microwaves would have as its ultimate standard the rotation of molecules or atomic nuclei. The question arises: which is a more reliable timekeeper, the spin of the earth or the spin of an atomic particle? The evidence leans toward the fundamental and universal constants of the atom. The spin of the earth changes; the moon, by gravity and by the friction of the tides, is gradually slowing it down.

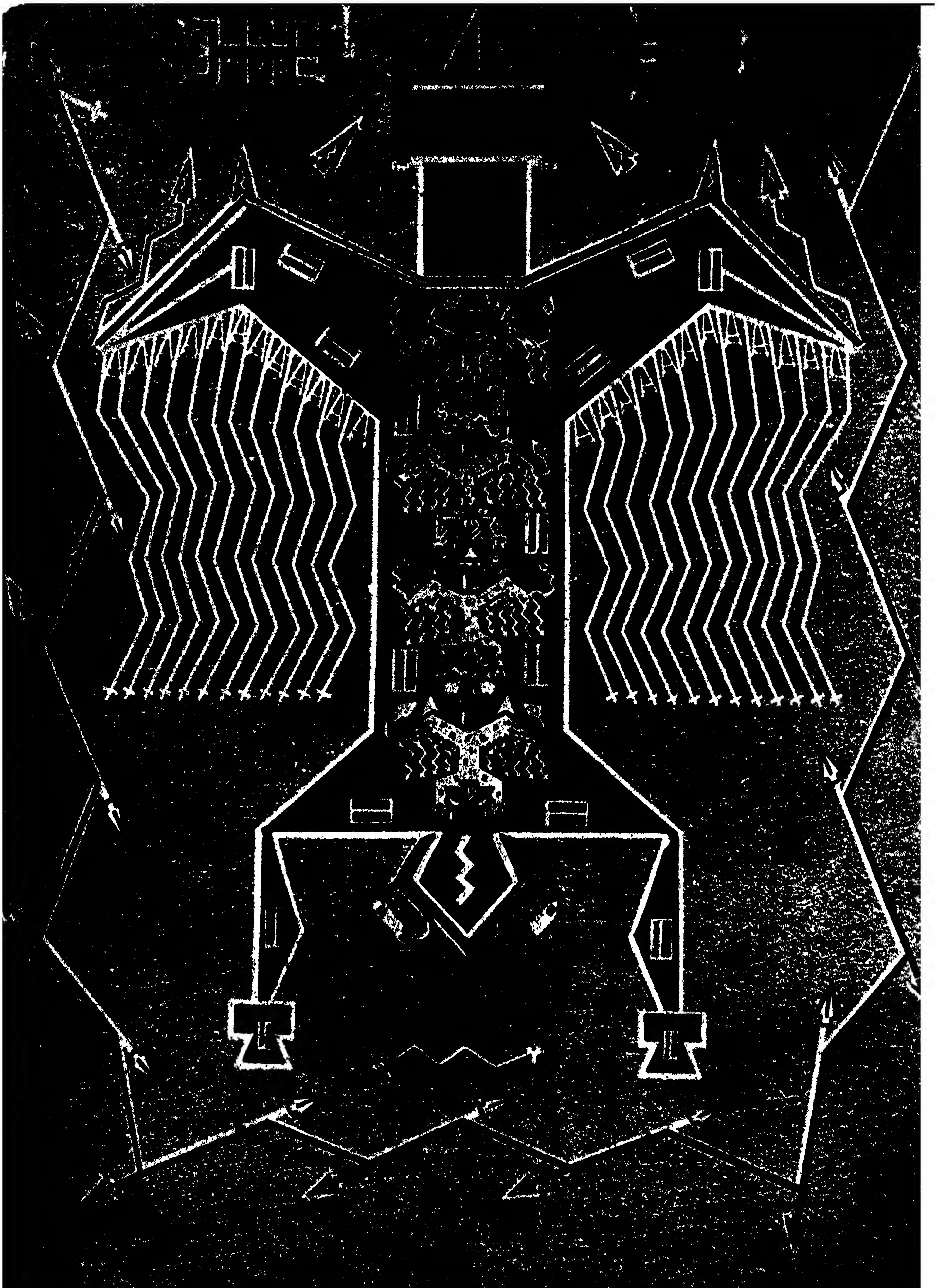
Already a number of laboratories are working on methods of measuring time by radio. At the moment, a tube of rarefied ammonia gas is favored as an experimental standard because of the excellent sharpness of its radio spectral lines. Just as the green line in the visual spectrum of mercury 198 may become the ultimate standard of length (SCIENTIFIC AMERICAN, August), a line in the radio spectrum may become the ultimate standard of time.

Thus, by a combination of optical spectroscopy with the new radio spectroscopy, science is on its way to obtaining not only a new insight into the structure of all matter but an immutable reference for its measurements of space, time and the dimensions of the universe.

Harry M. Davis is a professional science writer and author of the recent book Energy Unlimited.

APPARATUS of Bloch experiment placed tiny capsule of proton-rich material within transmitting coil.

MAGNET POLES about apparatus above caused hydrogen nuclei to line up and precess on their axes.



SHAGBARK HICKORY

A rough coat is the distinguishing feature of one of our handsomest native tree species, now retreating under the attack of man and other natural enemies

by Donald Culross Peattie

TO EVERYONE with a feeling for things American, and for American history, the Shagbark Hickory seems like a symbol of the pioneer age, with its hard, sinewy limbs and rude, shaggy coat, like the pioneer himself in fringed deerskin hunting shirt. The roaring heat of its fires, the tang of its nuts—the wild manna that it once cast down lavishly every autumn—stand for the days of forest abundance. With its marvelously strong and resilient fiber, it played a great part in our Age of Wood. Yet, tough and staunch though it is, old Hickory is now retreating before its modern enemies.

A Shagbark can usually be distinguished as far as it can be seen, by the smoke-gray bark which is forever warping away from its stem in great plates a foot or more long and six to eight inches wide. Frequently the strip is loose and curling at both ends, and is only more or less loosely attached at the middle. Its edges usually touch those of another strip of bark so that if one tries to pull it free from the trunk it is so engaged on both sides that one soon gives up the task. True, there are other trees with exfoliating bark, but none in our sylva with such great segments, so long or so thick. This shagginess begins to develop in comparatively young Hickories. Around the feet of old specimens the forest floor may be quite littered with the castoff heavy coat of armor. But the tree is not shedding its bark preparatory to some other condition—normally new shagginess simply thrusts the old away. Occasionally a tree has close, not shaggy, bark, and is called by lumbermen "Bastard Hickory."

In rich, deep soil Shagbark attains heights of 120 feet, and under forest conditions it may form a columnar trunk, free of branches for the first 50 to 60 feet. It tends to have a narrow crown, with short branches and heavy drooping branchlets; against the winter sky the outline of form and twigs is uncouth and scraggly. But the winter gales may wrench at it as they

HICKORIES stand above the grave of Andrew Jackson near Nashville, Tennessee. Jackson was given nickname "Old Hickory" by frontiersmen, to whom Hickory meant toughness.

will, for its very deep taproot makes it one of the most windfirm of trees. Spring is late in coming to the Hickory, and well after other trees have flowered or leafed out, this one stands forth, naked and massive, on the dry ridges and hillsides where it abounds. But about the first week in April the inner bud scales begin to open, arching out and twisting at the same time but with their tips at first still adhering

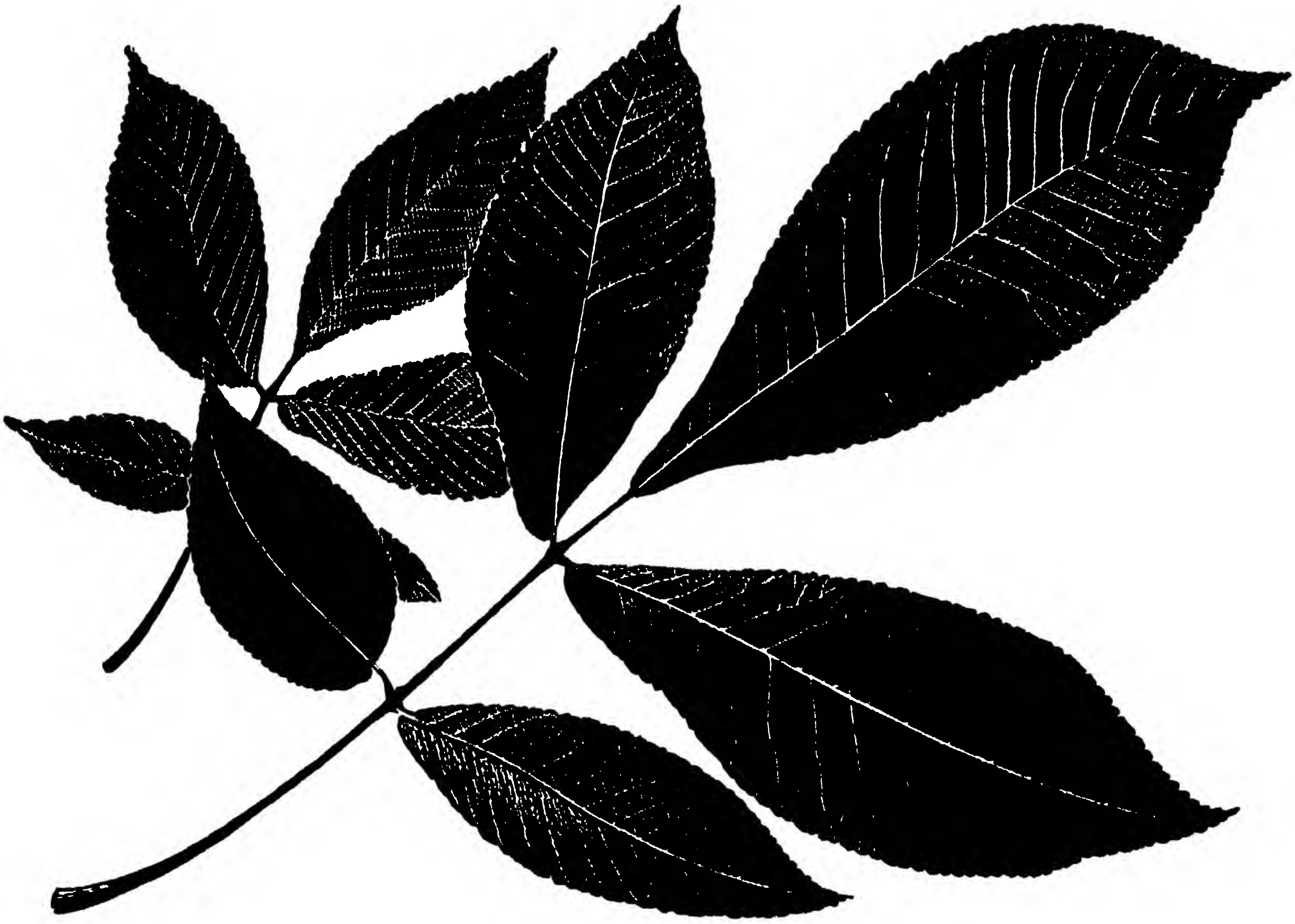
HICKORY NUTS, once abundantly cast down by the shaggy trees, were an important part of American pioneer life. Today its resilient wood is more in demand than it was then.

in a pointed arch. Shining and pubescent on the inner surface, and yellow-green richly tinged with red, they part finally and curl back almost like magnolia petals, luminous as spring sunshine and with the downy look of young life. The new leaves and catkins are then seen standing up in a twist, like a skein of green wool. The catkins now rush into growth simultaneously with, but more swiftly than, the delicate, pale and lustrous young leaves.

Dark, heavy, and aromatic is Hickory foliage all summer, but if the season is a dry one the leaves may begin to turn a dull brown even in August and drop, leaving the tree prematurely naked. Yet if they last through the summer, they join modestly in the autumn splendor of our middle-western woods, turning a soft dull gold that has a quiet beauty when the sun of Indian summer shines through them. To all who know the Shagbark, such memories are linked with visions of the violet smoke of asters curling low through drying grasses, with peeled October skies, with crow calls that telegraph your presence through the woods, and the shining of red haws, like little apples, on the thorn trees.

As early as 1640 our Hickory was described by an English botanist. And in William Strachey's *Historie of Travaile in Virginia Britannia* we read of a tree whose nut is "exceeding hard shelled and hath a passing sweet karnall; this . . . the Indians beat into pieces with stones, and putting them, shells and all, into morters, mingling water with them, with long woodden pestells pound them so long togither untill they make a kind of mylke, or oylie liquor, which they call *pocohicora*." From this Indian word, evidently, derives the name of Hickory.

As the Indians retreated before the coming of the white man, the stauncher virtues of the Hickory tree began to be apparent. For its wood is one of the heaviest we have, incomparably tough and resistant to shock and heat. The pioneers soon found this out. They made ramrods of Hickory for their rifles, and fenced in their cleared land with snake-rail fences—though it is one of the most difficult woods in the temperate zone to split and decays swiftly when exposed to the elements. The early furniture-makers discovered that seasoned rounds of Hickory in posts of green "sugar wood" (maple) made unbreakable joinery, for as the green wood shrank it clasped the iron-hard Hickory dowels forever. Green Hickory splits made good hinges for the pioneers' cabin doors. Of the shaggy bark they made boxes. Yellow dye from the inner bark tinctured the homespun of the cabin housewife. Hickory



THE LEAVES of Shagbark Hickory are narrow and pointed at the end. They appear later in the spring than the leaves of most other trees, budding early in April. Sometimes, if the summer is dry, Hickory leaves fall as early as August. Generally, however, they last until the leaves of the other hardwoods have begun to turn.

hoops encircled the ubiquitous pork barrel; they are not surpassed in general utility by the metal hoops of today.

INDEED, even in this age of steel the wood of Hickory is more than ever in demand. For Hickory is stronger than steel, weight for weight—more elastic, less brittle, less heat-conductive. Resistant as it is to an impact load, it is in the highest demand for ax handles and every sort of striking tool. Because of its low conductivity to heat, it is prized for wagon parts, like the hub, where the heat of friction may be great, or others, like the singletrees, that may endure a sudden strain. No wonder that the covered wagons rolled westward on Hickory hubs and Hickory felloes, or that Hickory sulkies have made the American trotting race famous. The terrific vibration on the big picker sticks in textile looms can be sustained only by Hickory. Skis, too, must stand violent strains, so that our Hickory is the most prized wood of skiers the world over. Indeed, it is not possible to imagine another wood that could replace our Hickories if all of them were depleted—a situation now looming well above the horizon.

In the vanished days of our abundance, there was Hickory literally to burn. And how they burned it! The log cabins, notoriously drafty if not perfectly constructed, were kept warm by a roaring fire day and night a large part of the year, and Shagbark was the favorite wood to feed this Moloch. For the fuel value of Shagbark is greater than that of any other American wood except locust. A cord of Hickory is almost equivalent in thermal units to a ton of anthracite, and even today costs less.

The green wood of Hickory is considered by epicures the perfect fuel for the preparation of smoked hams. The pioneers found this out, and no one has ever discovered a finer source of coals or fumes for this purpose. The aroma of burning Hickory enters into the ultimate taste of the smoke-cured ham as definitely as that of Spanish cedar in cigar boxes blends with the taste of the finest Havanas. It is true that, weight for weight (not volume for volume), white pine fuel has more thermal units, but for seasoning hams it would never have the long-lasting coals nor impart the subtle flavor of Hickory.

AS FOR the taste of Hickory nuts, no one who in his childhood gathered the little, hard-shelled kernels and, cracking them on an overturned flatiron, dug out the resistant treasure embedded within will ever admit a greater delicacy. For in that taste is all of autumn and old, gold days, a sense of the richly dying year, of abundance scattered from on high and of the trees themselves, tall, shaggy old sentinels watchful overhead. There may be men and women still living who can remember "nut cracks" like those that were a popular diversion of pioneer boys and girls. As many nuts were eaten after the gathering as young appetites could endure, and the rest saved for sale and future consumption. Quite as important as the nuts at these "cracks" were the kissing games played by the children and the courting among the older boys and girls. Today it is to be feared that even on farms nut cracks are a thing of the past; the farm children get to the country store and buy packaged peanuts, like the rest of us.

And the trees are going. The outlook for commercial Hickory has been admitted for years to be poor and getting worse. Long ago the great virgin stands were culled out of the forest. Many lumber companies are now reworking their second growth, and so intense is the demand that even this is hardly allowed to reach satisfactory maturity. For under forest conditions Hickory is a slow-growing tree, sometimes twice as slow as such a notoriously slow-growing species as white oak. Yet it is utilized wastefully, only the pale sapwood normally being accepted by buyers because of an unfounded prejudice that the darker heartwood is weaker. Scientific

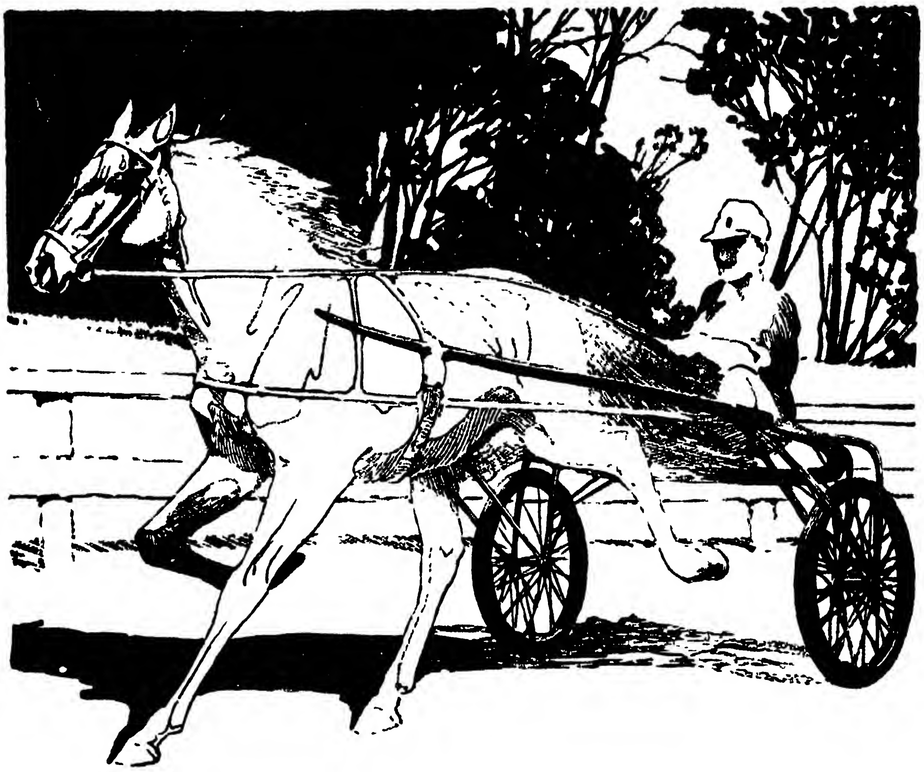
tests have not indicated this in the least.

More serious than any drain by man is the loss occasioned by beetles. It is odd that Hickory, one of the hardest of all temperate-zone woods, should be the especial prey of so many kinds and such untold numbers of wood-destroying beetles. One sort attacks the living tree and kills it: others then destroy the standing timber in the dead trees. Even sound Hickory when stacked in the woodyard is subject to invasion by still further kinds that turn its mighty sinews to thin rivers of sawdust. Such loss of Hickory was probably great even in primeval times, but injury from fire and overbrowsing by cattle has so weakened Hickory groves that their insect foes are forever quickening the pace of their destruction.

But Hickory fights for survival in its own stubborn way. Like flourishing backwoods children, the seedlings can come up through dense shade. So Hickory is a "pushing" species, able to succeed other hardwoods in the ecological course of events, able even to succeed itself, generation after generation, on the same land. It will also endure poorer soils and drier climates than many of our hardwoods. And when released from intense forest competition, it can put on comparatively fast growth where before it had been the slowest of all.

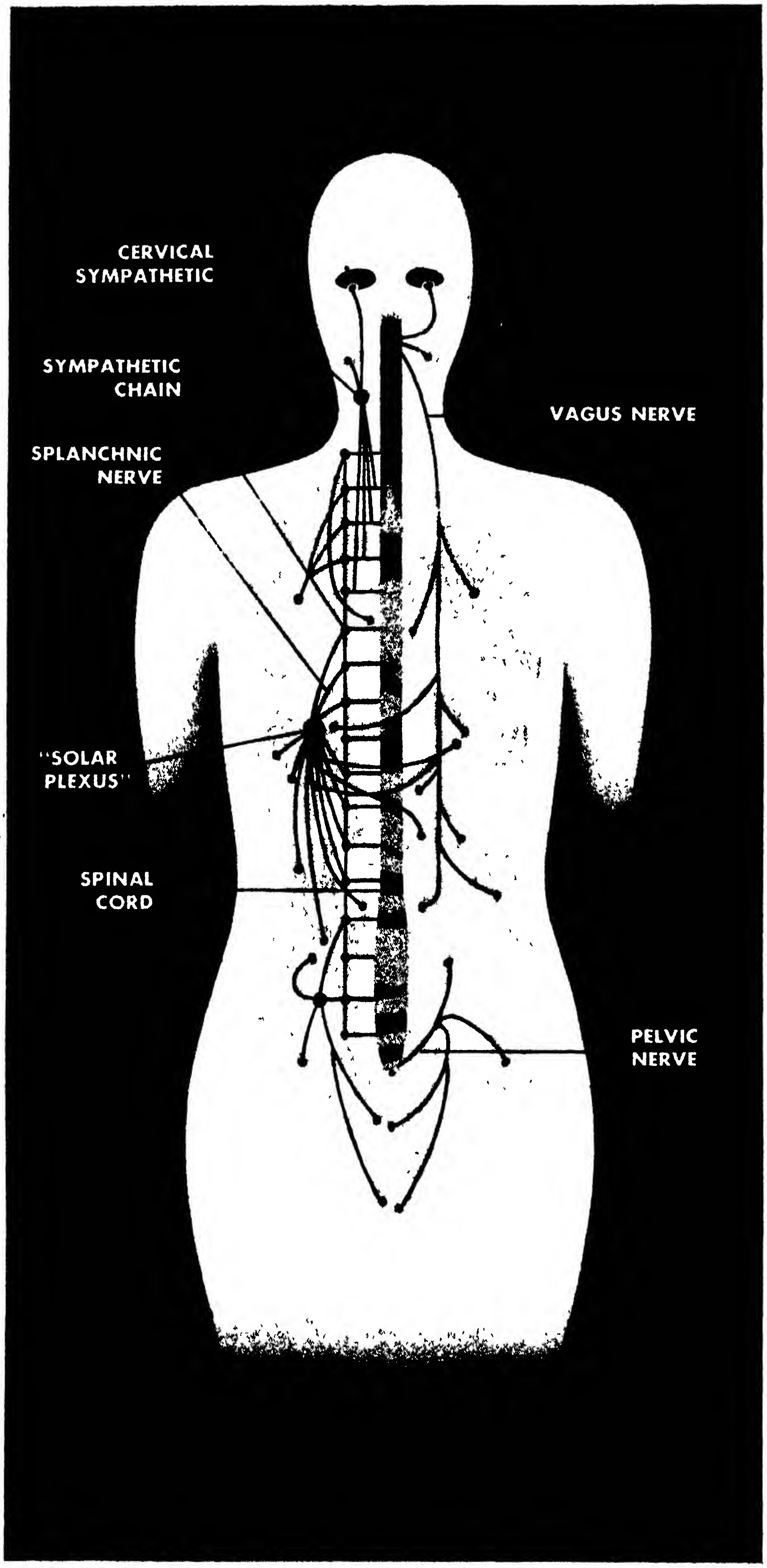
BUT, broadly speaking, there is no denying that Hickory is a tree of the past. It is true that here and there fine old Hickories still stand, widely scattered in farmers' woodlots, but they are survivors of a day that is gone. It was a stout-hearted day, and that Hickory was a symbol of strength in the minds of the men who lived then is attested by the nickname that they gave Andrew Jackson. It was accorded him in the War of 1812 when, a major general of militia, he received callous orders from the Secretary of War to discharge his troops at Natchez, where they were 500 miles from home. Flatly refusing, Jackson marched his men back along the Natchez Trace to Tennessee in order that they should be mustered out near their homes. Sharing their poor fare, sleeping with them on the hard ground, he wrung from the backwoodsmen their admiration. "He's tough," admitted the tough boys from the Hickory groves, "tough as Hickory." "Old Hickory," they called him, and the name carried him to the White House. Today he lies in his grave in "The Hermitage" garden near Nashville, in the shade of six towering Shagbarks. They are fit guardians for him, and noble reminders of the strong old days when America's character was forming.

Donald Culross Peattie is a botanist and author.



TROTTING SULKIES are made principally of Hickory. The wood of Hickory has traditionally been used where unusual toughness and resilience is needed. Now it is used mainly to make the handles of axes and other tools.

RAIL FENCES were one of the principal uses to which Hickory was put by early Americans. Because of its extremely high fuel value, the pioneers also burned Hickory in huge quantities to keep their drafty cabins warm.



THE AUTONOMIC NERVOUS SYSTEM, concerned with the internal adjustments of the body, is divided into the orthosympathetic (*black lines*) and parasympathetic (*gray lines*) systems. When one system effects an action, the other inhibits it. Both, however, start and inhibit various functions.

THE

THE NERVOUS system is principally concerned with sending some sort of excitatory message—through its own circuit and along the nerves connecting it with other parts of the body. Some kind of action is started, an excitation is set up, it travels along the nerve, excites something else, and produces action. It was known to the ancients that if a nerve was irritated, the muscle to which it went could be made to twitch. Yet if one thinks about this a moment (which did not happen for many centuries), it is obvious that stimulation is not the whole story. How would you like to drive an automobile that had an accelerator but no brake? Whenever fine control is needed, there is always a mixture of push and hold back. In the fine manipulation of a tool, a craftsman uses one hand to push the tool forward and the other hand to brake it When you make a sudden movement with some part of the body, you must stop the movement somewhere; it does not just go on until its momentum is spent. If you started to swat a fly on your face, and did not stop the movement as it approached its end, you would likely end up with a black eye.

It is obviously necessary, then, that the nervous system possess some kind of opposing mechanism. It must be able to excite, set into motion, start things; but it must also have a means of slowing, inhibiting, stopping, suppressing action. In spite of this obvious necessity, when inhibition was actually discovered about fourscore years ago it created a terrific stir in the scientific world and was not believed at all for some time. The Weber brothers in Germany were stimulating various nerves of the body to see what they did. They found one running down from the brain through the neck into the chest (the vagus nerve) which, when stimulated, stopped the heart. When stimulation stopped, the heartbeat resumed. So here was a most remarkable phenomenon, showing that nerve impulses could go along the nerve and, instead of starting something, could stop it.

It was later recognized that a certain part of the nervous system, the so-called autonomic system which is concerned

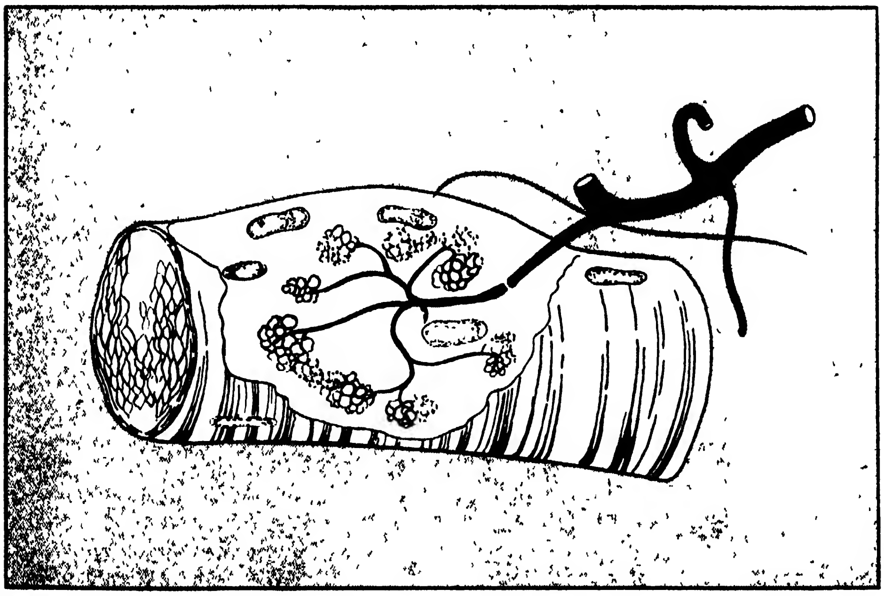
DYNAMICS OF INHIBITION

The nervous system, obviously, originates and transmits nerve impulses. But it must also possess a mechanism for stopping them

by Ralph W. Gerard

with the control of the viscera, has many nerves that can inhibit action, as well as others that can initiate it. And indeed the autonomic nervous system was still later found to have two portions, from both of which practically every internal organ receives nerves. The organ has a double innervation, as neurologists say. One of the nerves will excite it into greater activity, and the other will inhibit it.

The two parts of the autonomic system are the orthosympathetic and the parasympathetic. The vagus nerve (parasympathetic), for example, inhibits the heart; the orthosympathetic accelerates the heart. The vagus causes the gut to contract and the stomach to secrete; the sympathetic inhibits these actions.



SKELETAL MUSCLES, unlike the muscles controlled by the autonomic nervous system, are activated and inhibited by a single set of nerves. In this drawing, the muscle fiber is the large cylindrical structure. The nerve is the slender fiber that leads to "end plate" junctions with the muscle.

One might expect that the muscles of the arms and legs, the so-called skeletal muscles which are under voluntary control of the brain, might likewise have a double nerve supply: one to excite the muscle, and the other to stop its action. But the latter seems not to exist, although it has been looked for very carefully. In this case the starting and stopping are performed not peripherally on the organ itself, but in the central nervous system. Whether the muscle starts or stops depends on whether the nerve cell whose fiber goes to and activates the muscle is thrown into action or is stopped in its action. Thus the central nervous system controls both the excitation and the inhibition of our ordinary muscular movements.

Another example of centrally controlled inhibition is that of a simple reflex from the spinal cord. If the doctor wants to test your reflexes, one of the places he is likely to hit is just below your knee-cap; he taps it, your leg kicks out, and you both feel pleased with yourselves. The knee jerk is a perfectly routine, automatic reflex response; nevertheless it can be completely inhibited by a number of things, one of them being a slight painful stimulus to the same leg. If you stick a pin into the skin of your foot, the next tap on the tendon at the knee-cap will produce no knee jerk. In fact, the knee jerk may be inhibited for some seconds after a single sensory impulse comes into the same part of the spinal cord through a different nerve.

Even more remarkable is the teamwork of nerve impulses in your ordinary movements. You flex your elbow with the great biceps on the front of your arm and extend it with an opposing muscle on the back. Either maneuver requires very little effort, for when one muscle contracts the opposing one relaxes; it would be a great deal more difficult if, when flexing the arm, the flexor muscle had to overcome the pull of the extensor. When you stand, the extensor muscles in your legs are working hard to hold up your weight, yet you can easily raise a leg by contracting the flexor muscles, without using brute force to overcome the powerful contractions of the extensors. Something called reciprocal inhibition comes into action. Whenever a particular muscle contracts in ordinary reflex behavior, the opposing muscle is automatically inhibited. Its action is cut off. You do not have to think about it or do anything about it; it is part of the built-in mechanism of the nervous system. When you look to the side, a muscle on the outer part of the eyeball which pulls the eye laterally contracts, and at the same time the corresponding muscle of the other eye relaxes; an opposing muscle on the nasal side of each eyeball acts just in reverse. So the two eyes move together with perfect ease and timing. The muscles are so beautifully coordinated that one can study the contractions of the lateral muscle simply by measuring the relaxations of the medial muscle. Reciprocal inhibition is thus another striking form of central inhibition, seen at the spinal level and higher in the nervous system.

There is still another kind of inhibition which may or may not be closely related to these. It has been found in animals and in man as the result of accident—when the spinal cord, for example, is severed. For a time the reflexes of the lower part of the body are completely lost, but they gradually recover until finally they become exaggerated far above normal. The body develops hypersensitivity, or "hyper-reflexia," one might say. A light touch on the skin can provoke violent reflex movements of the

legs, emptying of the bladder, and so on. There has been a loss of some inhibition normally acting from the upper part of the nervous system on the lower part of the spinal cord; in addition, some local irritation may also be present.

Or again, if the cerebrum is disconnected from the underlying thalamus and hypothalamus, as has been done in animals, certain types of emotional-like behavior, the manifestations of which arise in these deep brain regions, are tremendously exaggerated. A cat, for example, with its cerebrum disconnected from its hypothalamus acts with little provocation exactly as does a normal cat in the presence of a barking dog. It shows what has been called "sham rage" (no one knows whether the cat really feels rage or not), and responds to the stroking of its back not by purring and rubbing its head against your leg but by going into a complete tantrum. Its claws come out, it strikes, it hisses, its back arches, its fur comes up, its tail thrashes—the full picture of an enraged cat. It displays an overactivity which normally, when the upper cerebrum is connected with the lower brain centers, is suppressed.

A recent extension of these studies to human beings, the operation called leucotomy, in some respects has comparable results. Some of the white connections between the frontal pole of the cerebrum and the thalamus are cut by passing a knife down through this part of the brain. The operation is used in certain cases of mental disturbance, in deeply and chronically depressed patients, for example. The operation may restore *joie de vivre* (and produce other changes perhaps not always beneficial). The subject becomes a much more contented individual and often a much more satisfactory one socially. Some of the inhibitions that operate from above—quite specific neural inhibitory messages—have been eliminated.

From the upper parts of the nervous system, connecting nerves descend by many pathways to act upon the spinal cord. There are, in fact, two complete arborizations—branching sets of nerve paths—that come from the cerebrum, the cerebellum and the midbrain, and run along the cord. One set, when activated, excites movement, *i.e.*, contracts muscles; the other relaxes them. Their course is still being worked out, and many have been traced only in the last year or two.

It has been known for a decade that when certain regions of the cerebral cortex are stimulated for only a few seconds, they act on other parts of the cortex so that a stimulus applied even minutes later (say to the motor cortex which ordinarily causes a muscle movement) is completely ineffective. Conversely, when the upper part of the brain is separated from the midbrain and cord, a so-called decerebrate rigidity results. The experimental animal goes into a condition of tremendously exaggerated muscle contraction; it becomes spastic, rigid. A cat so operated on is just like a sawhorse, standing like a toy on stiff legs that can hardly be bent by force. But if some of the paths that have been cut are artificially stimulated, it relaxes.

Similarly, when the cerebellum is removed, the result may be either exaggerated muscle tension or weakened tension, and the braking action mentioned earlier is often interfered with. The cerebellar patient may get a black eye when trying to scratch his nose, for his hand fails to stop at the intended goal. And a stroke, which disconnects pathways in the brain, may produce not only paralysis but also spasticity, or overcontraction of the muscles.

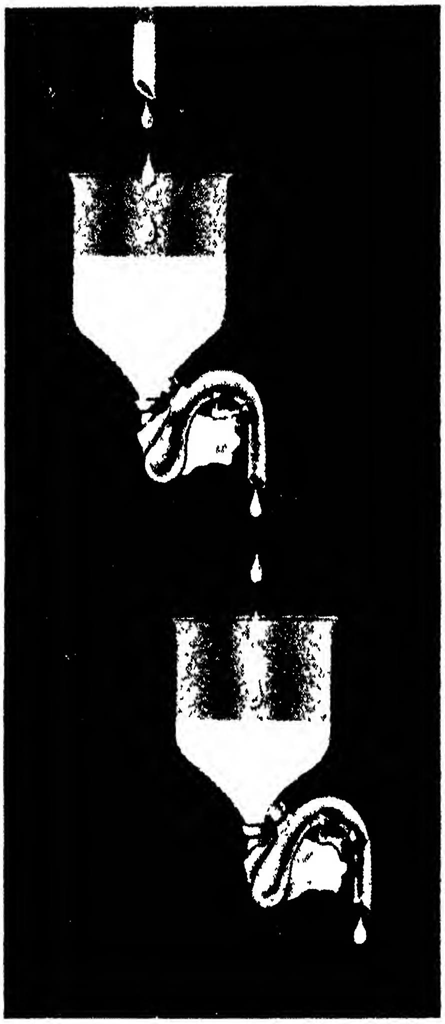
THERE are still other kinds of inhibitions in the nervous system. Ivan Pavlov suggested that in sleep, inhibition spreads slowly from one region over the whole cerebrum and, indeed, one can demonstrate such spreading inhibition in the electrical activity of the brain under certain conditions. This is probably too simple and vague an explanation of sleep, and there is evidence against it. But such inhibition may be related to those nightmares in which one is being chased by a bear and just cannot lift his legs to run. That awful feeling of being unable to move is probably due to a real internal inhibition of motor connections.

Then there are the voluntary inhibitions. If I make a sudden movement towards your face, you blink; but if I tell you I am going to make you blink, and you try hard not to, you can, with some practice and will power, avoid it. Under many conditions you can inhibit even crucial, self-protective reflex responses. The most basic reflex of the spinal cord is to pull a limb away from damage. When you step on something that causes pain, you flex your leg; when you touch a hot stove, you pull your hand away. These actions are perfectly automatic; the brain is not involved at all. But if you are warned "this plate is hot," you can deliberately hold on to it, even to the extent of getting a bad burn. This is a magnificent example of the power of inhibition!

Finally I mention, just for completeness, the thing with which people most commonly associate the word inhibition. You are full of inhibitions, the psychiatrists tell you, and psychoanalysis has demonstrated this to be so. Whether inhibitions at the psychological level involve the same nerve mechanisms as the physiological ones or whether they are something quite different is yet to be worked out.

We see, then, a panorama of many inhibitions, within the central nervous system and under the action of peripheral nerves. Obviously inhibition is a major phenomenon, even though it was not recognized until less than a century ago. And it is equally obvious that inhibition is definitely not the mere absence of excitation. If excitation is something positive, inhibition is not zero but something negative. It is just as real as excitation but has the opposite algebraic sign. Indeed, as both are studied more and more carefully, excitation and inhibition have been shown to be equivalent in many respects.

Nevertheless, the only thing that can propagate itself, that can make itself go from region to region in the nervous system, is excitation. Inhibition could not possibly propagate, for if something happens at one end of a nerve that stops activity, that inactivity will not activate the next region of the nerve. So here is an interesting problem. Only positive messages can run along nerve fibers. Indeed, it has been proved that the same kind of nerve message goes along the vagus nerve, which stops the heart, as along the phrenic nerve, which makes the diaphragm contract. In other words, the nerve message that inhibits is the same kind as that which produces activity. One can cut the vagus and phrenic nerves in the neck of an animal, cross-suture the central end of one to the peripheral end of the other, al-

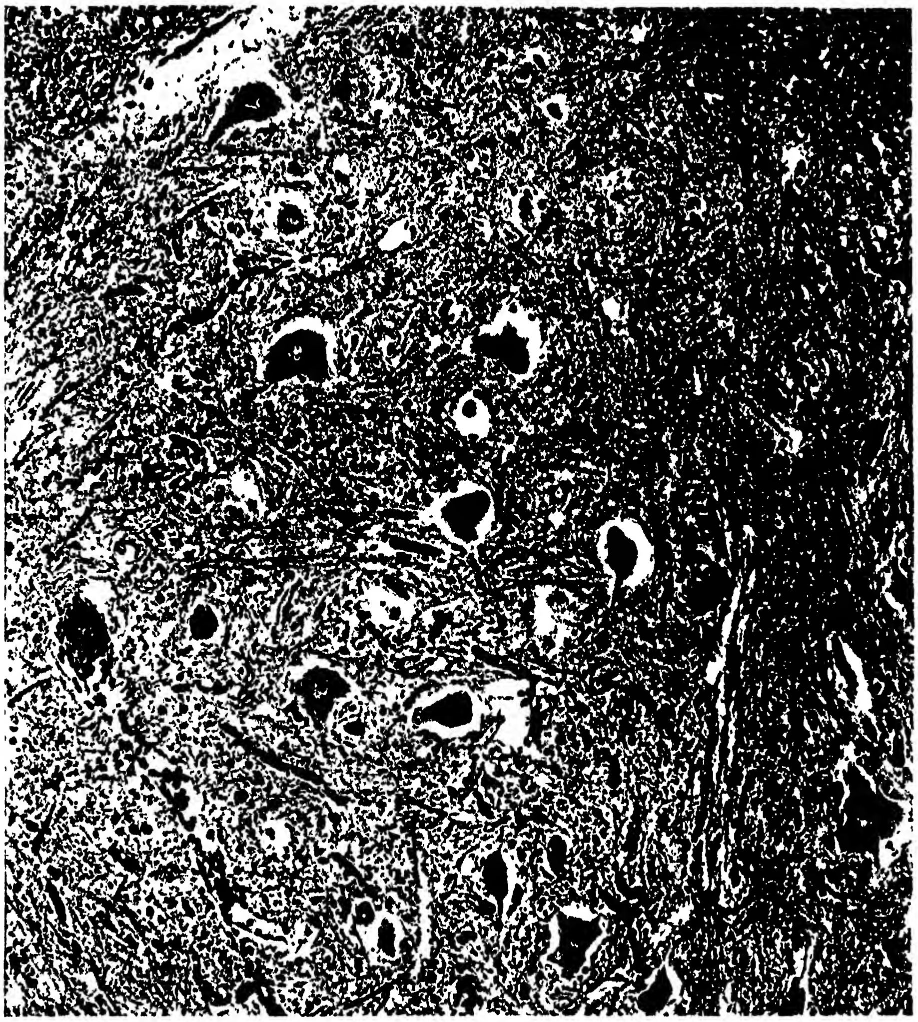


EXPERIMENT by Loewi passed solution through two beating frog hearts. When he stimulated nerve inhibiting heart 1, heart 2 stopped. This proved mechanism is chemical.

low time for the fibers to grow out again. and then stop the heart with the nerve that formerly caused a muscle to contract.

The inhibition, therefore, must somehow be achieved at the end of the nerve fiber, at the junction where the fiber joins another structure, where something is done by the nerve impulse that has gone along the fiber. These junctions—within the nervous system, or between nerve and muscle, or nerve and gland—have quite striking properties, and they are comparable, but opposed, for excitation and for inhibition. For example, if a nerve trunk is stimulated in the middle of its length, as when you strike your funny bone, the nerve messages go equally well in both directions. But when a nerve message enters the spinal cord and reaches the synapses (junctions) between nerve cells, it will go from the sensory side to the motor side very nicely, yet it will not go in the reverse direction. The same thing is true for inhibitory messages. Again, when a nerve is given a stimulus not strong enough to excite, the stimulus can be repeated a second later, and again a moment later, and still fail to excite. In the case of the reflex, however, a stimulus which does not produce any response at all on a single attempt may, if repeated a few times, produce a very good response. There is some kind of building up, called summation, of excitation in the central nervous system. Similarly, inhibition can build up in the neural centers.

The similarity of exciting and inhibiting messages is shown by still another phenomenon. When a nerve impulse is set up by a stimulus, it runs along the nerve and that is the end of it; the response occurs in a thousandth of a second and is finished. The nerve will not respond again unless stimulated again. But in the reflex the reaction is different. A single sensory impulse sweeping into the spinal cord may cause the muscles to contract reflexly for a large fraction of a second, even for many seconds. This also can happen with inhibition. A pinprick or other stimulation of a pain-carrying nerve can inhibit the knee jerk for some seconds afterward; there appears what is called after-discharge. The message runs into the nervous system promptly, but it does not have to come out and disappear immediately. Things can go on happening in the centers for a long time; the flavor lingers, so to speak.



NERVE TISSUE is an intricate mass of nerve cells and their branching processes. This section was cut from the spinal cord. Each cell has a main body. From it branch fine dendrites and one long process, the axone. Cell bodies of the regular nervous system are located in the brain and the spinal cord. Cells of the autonomic nervous system are scattered about the body.

BOTH excitation and its opposite, inhibition, are produced by a single kind of nerve impulse reaching the synapse. In one case the cell is thrown into positive activity; in the other case the activity is cut off dead. How does it work? There are, in general, two kinds of mechanisms that are theoretically possible.

One is chemical. The nerve ending, when activated by the impulse, could give a minute squirt of some chemical which in the one case excites the cell, in the other suppresses the cell. One kind of ending might squirt out acid, for example, and the other kind alkali.

The other possible mechanism is physical. The electrical fields or currents which travel with the nerve impulse could act from the nerve ending on the cell either to excite it or to inhibit it, depending on the conditions.

That was all we had to go on until relatively recently, and it was pretty vague and unsatisfactory. The break in the story came, perhaps, in 1921 with experiments by the Austrian physiologist Otto Loewi, who got the Nobel Prize for his discovery. He conceived a very simple idea and performed a very simple experiment. Loewi reasoned: "If the vagus nerve inhibits the heart by liberating at its endings in the heart a chemical that stops the beat, I should be able to pass some inert solution through frog heart 1 and then through frog heart 2, both hearts beating in tandem (the frog heart will beat perfectly well outside the body), and when I stimulate the vagus nerve to heart 1, the substance should be carried along in the solution from heart 1 to heart 2 and both should stop their beat." The experiment worked.

Further, Loewi found out what the chemical was. He suspected that it was acetylcholine, for it was known that this substance, when added to the heart, could stop its beat. Subsequent work showed that when the vagus is stimulated, acetylcholine is actually liberated from the inhibited heart. But why does the heart start again? Why, even when the acetylcholine is not washed away, is its action only temporary? More experiments showed that there is an enzyme, choline esterase, present in the heart and other tissues, which has the ability to split acetylcholine into the inactive chemicals choline and acetic acid. A tremendous amount of work done since the original Loewi experiments has demonstrated that the same thing happens at similar visceral (parasympathetic) nerve endings of the autonomic nervous system; that acetylcholine is liberated when the vagus or allied nerves are stimulated; that it stops the heart, contracts the gut, and so on,

just as the nerves themselves do. In the same way, the American physiologist Walter B. Cannon, who should have shared in that Nobel Prize, showed that the other branch of the autonomic nervous system, the orthosympathetic, also liberates a chemical when stimulated, which he called sympathin. It is only in the last year that we have learned that this substance is probably noradrenalin, related to the adrenalin from the adrenal glands, which also acts upon the viscera.

In the case of the viscera, then, there is evidence of two kinds of chemicals, produced by the two kinds of nerves. One leads to excitation of a particular organ, the other to inhibition of the same organ. It occurred to the English physiologist Sir Henry Dale, who did share the prize with Loewi, that the same process which took place in the viscera might also work in skeletal muscle. He found that he could produce twitchings of the muscles of an arm or leg by injecting acetylcholine, provided that he first paralyzed the enzyme choline esterase to prevent the destruction of acetylcholine. Several drugs cause such paralysis of the enzyme—eserine, prostigmine, some of the "nerve poison" gases of the recent war—and these today are being used clinically with some success in the treatment of neuromuscular paralyses or overactions.

One might imagine the same process working in the central nervous system: the ending of a nerve fiber produces a tiny squirt of acetylcholine—a tiny jet that carries activity across the synapse and fires the next nerve cell; then the enzyme breaks down the stimulating substance and the cell becomes quiet again. This would account for the impulse going only in one direction. It would account for a building up of excitation; as successive impulses come in, each one squirts a little more acetylcholine until enough accumulates to fire the cells. It could be made to fit the phenomena of reflex excitation: one can, indeed, get tremendous excitation of the brain by adding acetylcholine, or by injecting eserine to stop the destruction of acetylcholine already there. Unfortunately, no substance has been found or suggested that might explain inhibition.

Despite the attractiveness of this theory, many physiologists doubt that this chemical mechanism is responsible for excitation or inhibition or is of importance in transmission across junctions in the central nervous system, even though it probably does operate in the autonomic nervous system, where it was discovered. We must consider the alternative explanation of these phenomena: electrical action.

When a nerve impulse travels along a fiber, a wave of electrical change accompanies it. If the nerve is connected to a cathode-ray oscilloscope, the electron beam moves up when the impulse reaches the point on the nerve to which the first electrode is attached, moves down when the impulse reaches the second electrode and then comes back to normal. The changes all take place in a few thousandths of a second. If the impulse is stopped after passing only one electrode, a so-called "pure monophasic action potential" appears on the oscilloscope; it shows as a sharp electric flick, always moving with the impulse along the nerve.

Normally, the nerve fiber is charged like a battery—positive outside and negative inside. If a short circuit is made through its surrounding membrane (as if one scraped away the insulation between wires), currents are bound to flow from the adjacent regions through the shorted patch. Just such breakdown occurs in the membrane as a nerve impulse travels, and this is associated with

CLOSEUP of nerve cell bodies shows their branching processes more clearly than photograph on previous page.

the action potential and currents. Actually, currents flow out from a resting part of the nerve fiber, over half an inch away, back into the active region, and return along the core of the fiber to complete the circuit (*see drawing on opposite page*).

The currents are bound to run out in the space around the nerve fiber, actually rather like magnetic lines of force between the poles of a magnet. If another nerve fiber is near the active one or a nerve cell is at the end of it, some of these electrical currents must flow through the next unit, through the other nerve fiber or cell, and act upon it. Nerve cells and fibers are extraordinarily sensitive to electric currents. Currents going through them in one direction tend to excite them, and currents going through them in the opposite direction tend to suppress them. Neural activity can even be fully suppressed by electric currents, as in electric anesthesia or electric narcosis. An animal can be completely anesthetized with appropriate electric currents, and with no attendant damage. So the possibility suggests itself that such intercellular currents can produce both excitation and inhibition. Moreover, some of the electrical changes in nerves last much longer than the thousandth-of-a-second action spike; these effects, called "after-potentials," may actually increase for a minute or two after activity and then fall off very slowly. So there is plenty of residual electrical effect from nerve impulses to account for summation and after-discharge and many other things.

To study what happens at the junction between motor nerve and skeletal muscle, single nerve-muscle units have been successfully dissected out from the hundreds of thousands that are present in any ordinary-sized muscle. When a nerve is stimulated, an impulse runs to the junctional region at the end plate and produces a large electric change—the end-plate potential. This potential may be studied with the aid of the drug curare, used a great deal these days by surgeons to relax muscles during operations. Curare paralyzes the connection between the nerve and the muscle. The nerve messages reach the muscle but do not make it contract. Somehow the message is blocked at the end plate. Under the action of larger and larger doses of curare, the end-plate potential gets lower and lower and the muscle response starts later and later until, when the end-plate potential has been cut down by the drug to about a third of normal, it never does start the muscle response. In other words, this electrical change at the end plate, not a squirt of acetylcholine, apparently is the agent for stimulating the muscle. Curare has no particular effect on acetylcholine but it does cut down the end-plate potential, and when the potential is cut to a critical level, blockage occurs.

IN THE CENTRAL nervous system one can find somewhat comparable situations. The frog brain, removed from the animal, gives a beautiful, regular electrical rhythm, a brain wave much like that obtained from the human cranium. A large dose of caffeine stops the regular waves, but at intervals of a few seconds great electric spikes appear. They spread slowly from one end of the frog brain to the other as cell after cell becomes active. They look for all the world like the electric waves that one sees in the human brain during an epileptic attack. These spreading waves can cross a complete cut through the entire frog brain, provided that the cut is made with a sufficiently sharp blade and the halves are put together again so carefully that one cannot see where the cut has been made. The

convulsive potentials travel right on across it. This spread could not possibly be due to a chemical liberation. It can only mean that electrical currents, jumping the tiny gap, excite the cells.

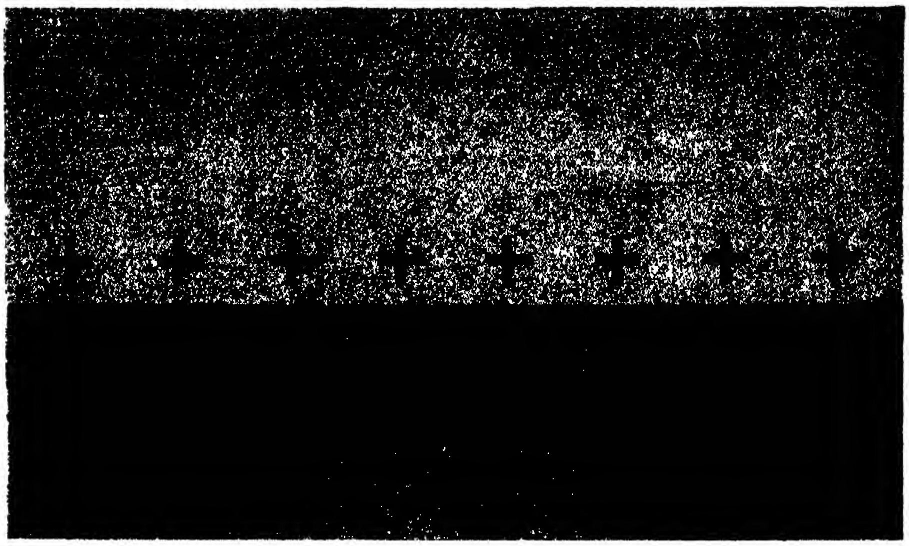
All this deals with excitation. There is good evidence that at the junction of autonomic nerves with their gland or muscle effectors excitation can be produced by one chemical substance, inhibition by another. In the central nervous system the evidence for the chemical agents is very unsatisfactory, but the evidence for electrical transmission is extremely good. One can account for excitation by the currents which flow from one part to another, from one cell to another. But how about inhibition? The waves in the frog brain can be started by passing a feeble current through the brain in one direction, and stopped by a current in the reverse direction. So inhibition is at least possible on an electrical basis.

It might work in this way: There is evidence that in the neurone there is normally a potential difference between the dendrite end, where impulses come in, and the axone end, where an impulse goes out. Suppose that in order to fire a neurone and produce excitation, this potential difference must be decreased to a certain extent. Then whether there is excitation or inhibition will depend upon which end of the neurone receives an addition to its electrical charge. Every nerve impulse that reaches the axone end of the cell will contribute its little negative electrical wave to make that end less positive until the cell fires. Exactly the same kind of impulses, delivering their negative electric currents at the dendrite end of the cell, will make the axone end relatively more positive and so tend to stop activity and inhibit, just as the same weight at one end of a seesaw or at the other end will make a given end go down or up.

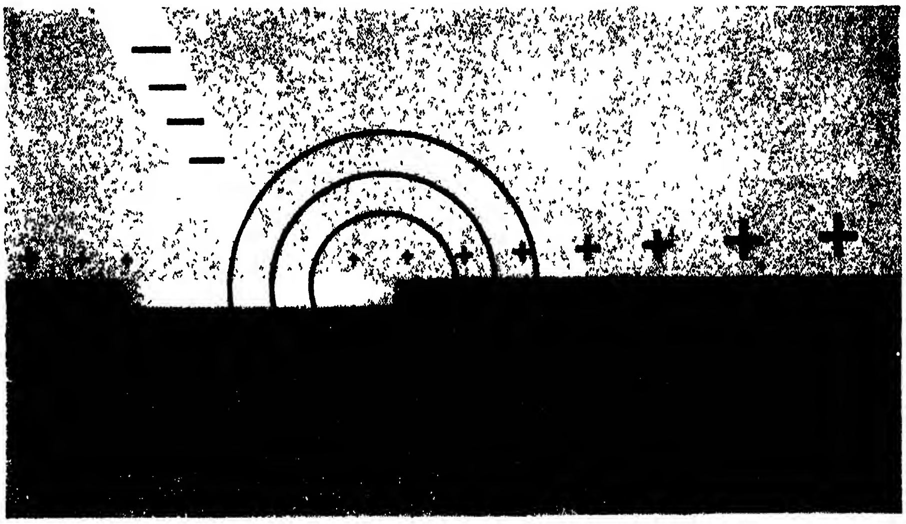
Very recently another theory of inhibition, closely related to this one, has been proposed. It suggests that a particular cell near the inhibited one does not quite fire off, but passes on electrical currents which are in the right direction to inhibit the cell instead of exciting it.

Although these theories are too involved to explain fully in this brief article, I hope I have made clear the tremendous importance in the nervous system, as everywhere else, of a brake as well as an accelerator, of opposing influences operating throughout the nervous system. Within the next decade, the phenomenon of inhibition, which only 80 years ago utterly mystified biologists, should become well understood.

Ralph W. Gerard, author of the books Unresting Cells *and* The Body Functions, *is professor of physiology at the University of Chicago.*



SURFACE OF NERVE FIBER, here shown in highly schematized cross section, is covered by thin membrane (*darker gray*). Outside of membrane is charged plus, the inside minus. Potential across membrane is .03 to .06 volt.



MEMBRANE OF NERVE is depolarized by touching it with a negatively charged electrode (*upper left*). Current is now able to flow across the membrane, neutralizing charge of positive and negative ions on both sides.

NERVE IMPULSE TRAVELS on the surface of the nerve when current flowing across the membrane depolarizes section farther along the nerve. Membrane is then repaired and its positive and negative charges restored.

"HOW NICE TO BE A PHYSICIST"

Songs by Arthur Roberts

Arthur Roberts is a talented physicist at the State University of Iowa. He is also a talented amateur composer and lyricist. The two songs on these pages, originally written for the enjoyment of his colleagues, are from a group of six that was recently recorded. Accompanying the records is the statement: "Any resemblance to existing persons or institutions is entirely malicious and premeditated."

TAKE AWAY YOUR BILLION DOLLARS

Upon the lawns of Washington the physicists assemble.
From all the land are men at hand, their wisdom to exchange
A great man stands to speak, and with applause the rafters tremble.
"My friends," says he, "you all can see that physics now must change.
Now in my lab we had our plans, but these we'll now expand,
Research right now is useless, we have come to understand.
We now propose constructing at an ancient Army base,
The best electronuclear machine in any place. -Oh

"It will cost a billion dollars, ten billion volts 'twill give.
It will take five thousand scholars seven years to make it live.
All the generals approve it, all the money's now in hand,
And to help advance our program, teaching students now we've banned.
We have chartered transportation, we'll provide a weekly dance,
Our motto's integration, there is nothing left to chance.
This machine is just a model for a bigger one, of course,
That's the future road for physics, as I hope you'll all endorse."

And as the halls with cheers resound and praises fill the air,
One single man remains aloof and silent in his chair.
And when the room is quiet and the crowd has ceased to cheer,
He rises up and thunders forth an answer loud and clear:
"It seems that I'm a failure, just a piddling dilettante,
Within six months a mere ten thousand bucks is all I've spent.
With love and string and sealing wax was physics kept alive,
Let not the wealth of Midas hide the goal for which we strive.—Oh.

"Take away your billion dollars, take away your tainted gold,
You can keep your damn ten billion volts, my soul will not be sold.
Take away your Army generals; their kiss is death, I'm sure.
Everything I build is mine, and every volt I make is pure.
Take away your integration; let us learn and let us teach,
Oh, beware this epidemic Berkelitis, I beseech.
Oh, dammit! Engineering isn't physics, is that plain?
Take, oh take, your billion dollars, let's be physicists again."

HOW NICE TO BE A PHYSICIST

How nice to be a physicist in 1947,
To hold finance in less esteem than Molotov does Bevin,
To shun the importuning men with treasure who would lend it,
To think of money only when you wonder how to spend it,
Oh,
Research is long,
And time is short.
Fill the shelves with new equipment,
Order it by carload shipment.
Never give
A second thought
You can have whatever can be bought.

How nice to be a physicist in this our year of grace,
To see the scornful world at last admit your rightful place,
To see the senators defer to every wise pronouncement
To fascinate the women's club, and star at each commencement,
Oh,
Research is long,
And time is short.
Drink your fill of adoration,
Glory in the new sensation,
Never give
A second thought
Sinatra holds a place that many sought.

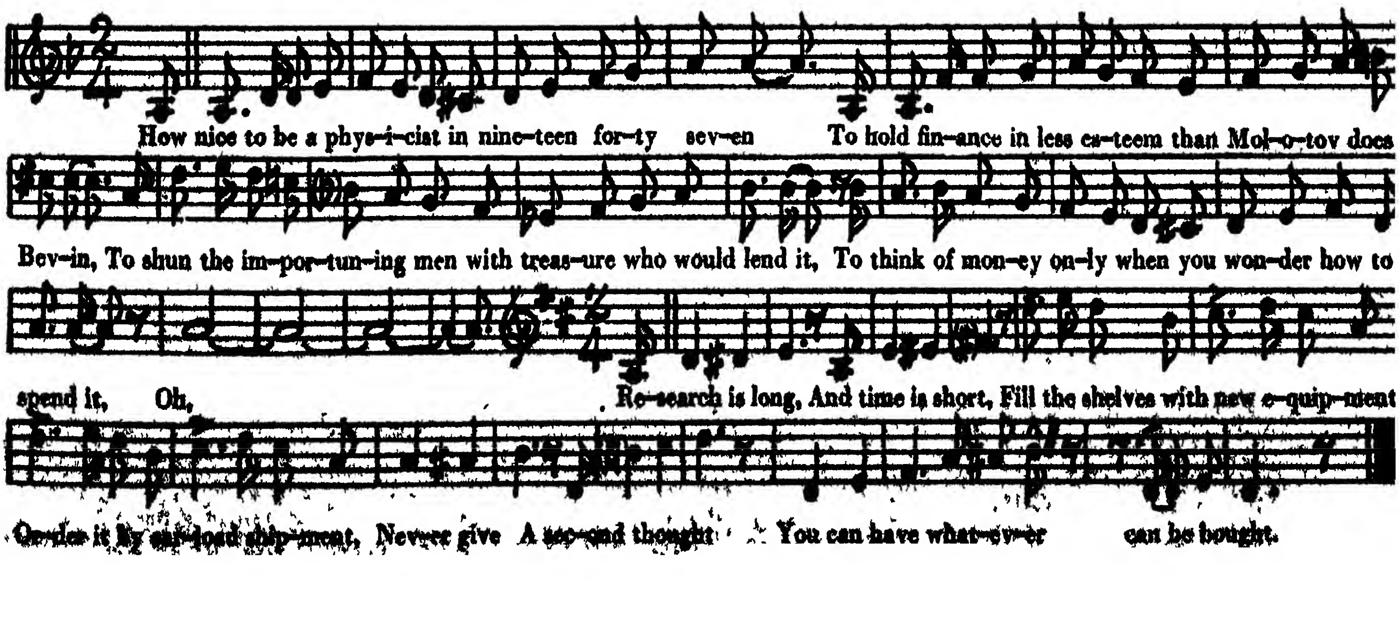
But have you sought a physicist and place for him to dwell,
And searched the town in vain to find a vacant dungeon cell
Or tried to teach a thousand students who can't do a sum
The girls who'd like to be Greer Garson finding radium?
Oh,
Research is long,
And time is short.
Toward the thesis drive the student,
Physics was his choice imprudent,
Never give
A second thought
Brains are still a thing that can't be bought.

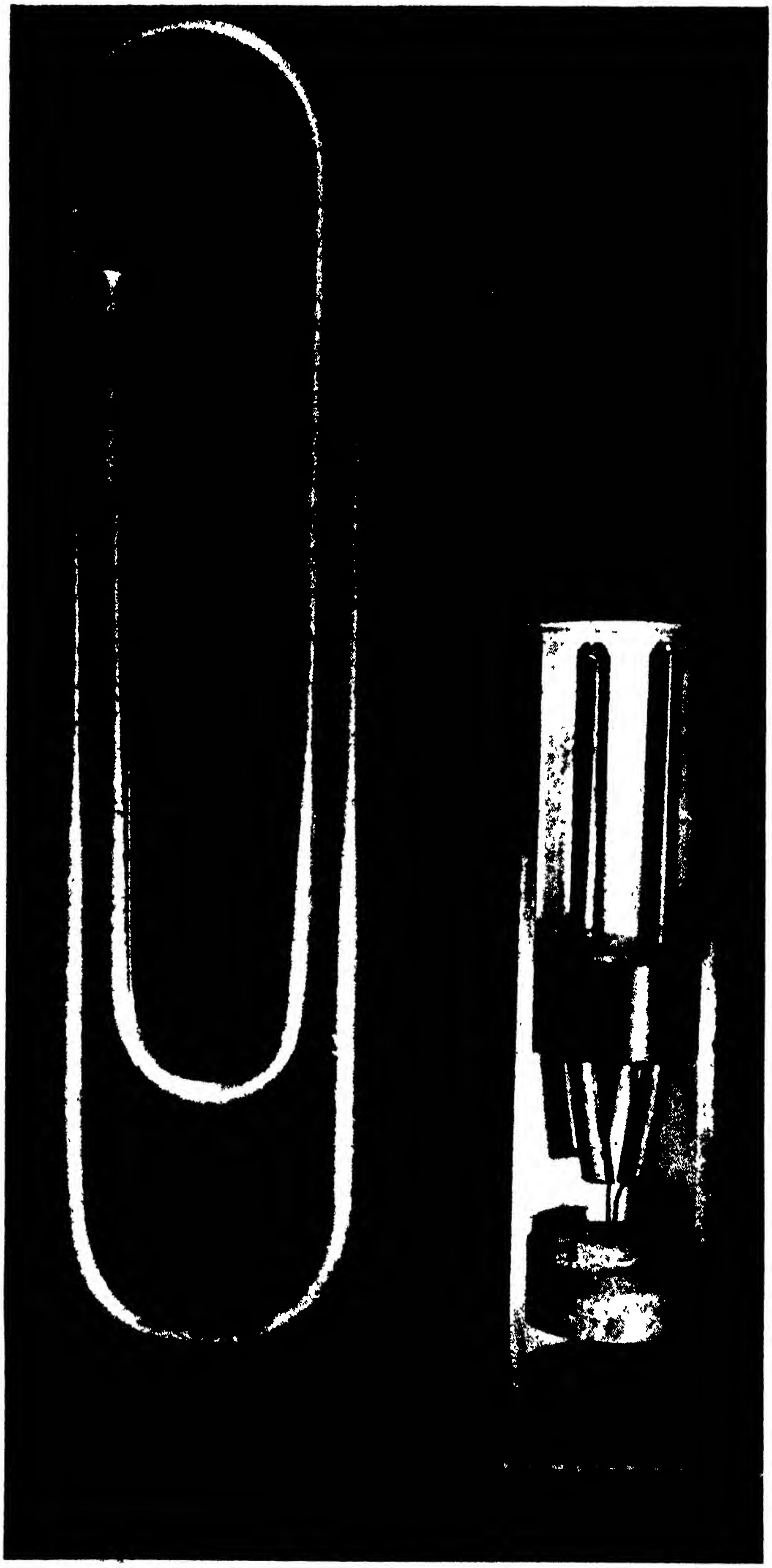
Oh did you write a book on fission which you tried to sell?
Or wonder while you lectured what you could or couldn't tell?
Or try to get declassified some nuclear equations,
Or wonder if the work you do was done at secret stations?
Oh,
Research is long,
And time is short.
If you find a fact essential,
Classify it confidential,
Never give
A second thought
The F.B.I.'s approval must be sought.

How nice to be a physicist in 1947,
How nice...?
How long do you think it would take to learn something about butterflies?

TAKE AWAY YOUR BILLION DOLLARS

HOW NICE TO BE A PHYSICIST





PAPER CLIP AND TRANSISTOR are compared to emphasize the transistor's size. Metal tube of transistor is cut away. Germanium crystal is tiny block on disk at bottom. Two cat's whiskers are mounted on heavy leads.

IN 1906 a young American electrical engineer named Lee De Forest discovered that if an electrified wire grid was placed across the path of a stream of electrons in a vacuum tube, the flow of electrons could be controlled in some rather interesting ways. The flow could be interrupted, reduced or stopped entirely; a feeble current of electrons entering at one end of the tube could be "amplified" to a powerful current at the outgoing end. It was this classically simple invention by De Forest that gave birth to the tremendous technology of electronics. From it came radio, television, radar, X-ray cameras, electron microscopes, guided missiles, electronic calculators, robot machine tenders, electronic burglar alarms, instruments that examine materials for invisible flaws, doors that open themselves—and doubtless greater wonders are yet to come. The electronic tube is easily one of the most ingenious inventions and most versatile tools of our fabulous century.

Since De Forest's elementary discovery, the electronic tube has been developed enormously. Electronic theory also has advanced rapidly, and it now appears that the vacuum tube is far from the last word. Within the past few months a group of physicists at the Bell Telephone Laboratories has made another profound and simple finding which may rank in importance with that of De Forest. In essence, it is a method of controlling electrons in a solid crystal instead of in a vacuum. This discovery has yielded a device called the transistor (so named because it transfers an electrical signal across a resistor) which can do many of the things that a vacuum tube does. Indeed, it has certain advantages over the vacuum tube. It reduces the complicated, delicate tube to a simple rig consisting basically of a couple of fine wires—cat's whiskers in the radioman's language—and a small crystal; no vacuum is needed. The transistor does not need to heat up, as a vacuum tube does, and so it goes to work instantly. It operates on a tiny amount of power—about one tenth of that used by an ordinary flashlight bulb. And it can be made almost vanishingly small. The present experimental model is about the size of the eraser on the end of a pencil.

The technological fruits of this inven-

THE TRANSISTOR

Basic research in the electrical properties of solids has opened up an entirely new way of manipulating electrons to do useful work

by Frank H. Rockett

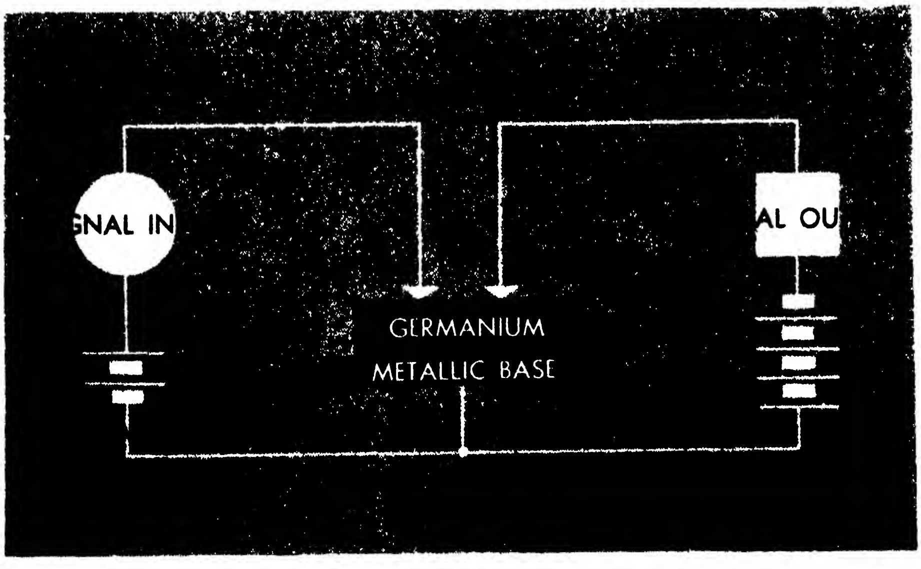
tion already appear extensive. The size of vacuum tubes is an important consideration in electronics, for it largely determines the size of the apparatus in which they are used. A television receiver requires about two dozen tubes; the celebrated computing machine at the University of Pennsylvania known as ENIAC has 18,000. With ingenuity and painstaking labor "subminiature" vacuum tubes only an inch long have been produced for some special purposes, but the transistor promises to reduce electronic equipment in general to an even smaller scale. Not only is the transistor itself tiny, but it needs so little power, and uses that little so efficiently (as a radio amplifier its efficiency is 25 per cent, against a vacuum tube's 10 per cent) that the size of batteries needed to operate portable devices can also be reduced. Thus the transistor makes possible tinier hearing aids, really small portable radios, more compact electronic devices for aircraft and a great reduction in the bulk of stationary equipment. In combination with printed circuits—the compact new wiring system—it may open up entirely new applications for electronics. The transistor also suggests the possibility of a considerable improvement in telephone transmission, because amplifiers for long-distance cables can be built small and mounted inconspicuously on telephone poles, and a miniature amplifier may even be built into the telephone receiver to strengthen weak signals.

Beyond this, the transistor vastly simplifies the manufacture and maintenance of electronic equipment. Because of its simple, sturdy construction, it will be longer-lived and possibly less costly than vacuum tubes. The transistor has important limitations: its power output in the present research stage is small (a maximum of about one fortieth of a watt), and the highest frequency at which it can operate is about 10 megacycles (10 million cycles per second). But its power and frequency range are sufficient for most purposes in the regular broadcast, television and short-wave regions of the radio spectrum.

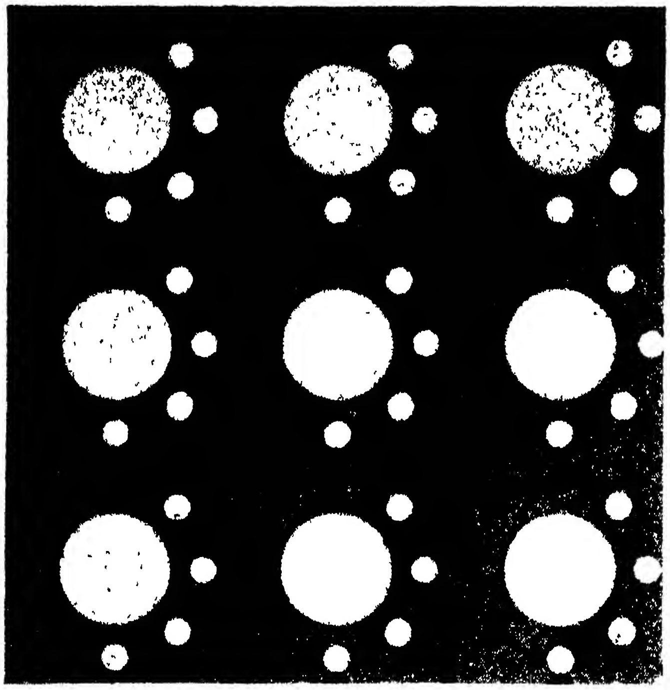
The transistor is the unexpected product of purely scientific curiosity. To understand how it was conceived and how it works one must examine the functions of the electronic tube and the way in which electric current is conducted by a solid. The basic purposes of an electronic tube are to convert an alternating current into a direct current (called rectification), to amplify the signal, to break it up into pulses instead of a continuous wave, or to make it oscillate, *i.e.*, beat in a regular rhythm at a calculated frequency. The tube itself was invented in 1905 by the English physicist J. Ambrose Fleming, who observed that if an alternating current was passed to a filament inside a vacuum tube the electrons would boil off the end of the filament as free particles and would travel across the vacuum to a positively charged plate at the other end. (This phenomenon, known as the Edison effect, had been noticed much earlier by Thomas Edison, but he had been unable to explain it and had made no practical use of it.) As long as the current was kept on, the electrons would move only towards the attracting positive plate; hence the tube was an easy means of changing alternating current into a direct, one-way signal. Fleming's tube, called a diode because it had two electrodes—the filament and the plate—could be used as a detector for radio signals. But De Forest's addition of the grid to control the electrons, making the tube a triode, was the step which gave the tube its great versatility and usefulness. Now the signal could be controlled and amplified (since a small number of electrons on the grid governed the flow of a much larger number from the filament to the plate). It could also be modified in other ways.

When not in a vacuum, electrons obviously are much less easy to control, since they cling more or less firmly to orbits about the nuclei of atoms. Whether a solid will conduct electricity depends on the degree of freedom of its electrons. Copper, a good conductor, has a single electron in its outer orbit or shell and this relatively free electron readily serves to carry current. Most metals have such loosely held electrons, hence are good conductors. On the other hand, an element such as sulphur, whose electrons are all locked in place by tight bonds with the nucleus and with other atoms, does not conduct electricity; it is an insulator.

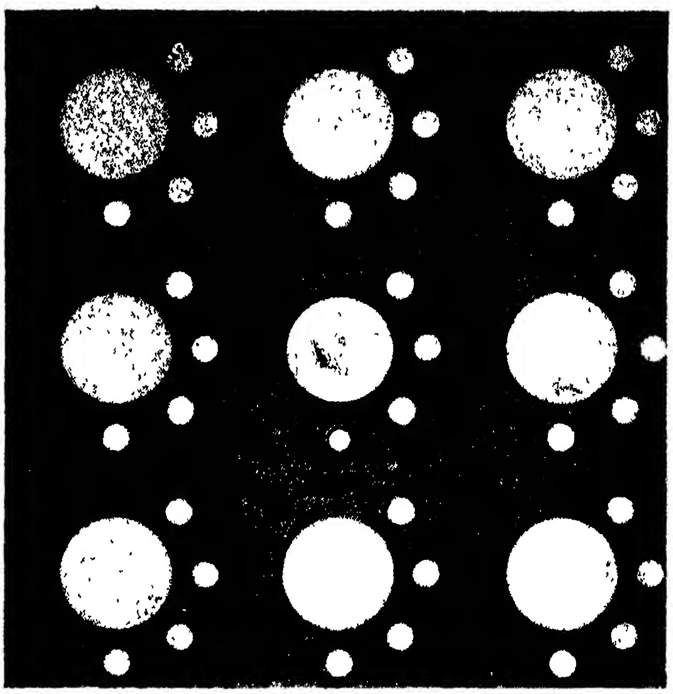
BETWEEN these extremes there is a class of materials known as semiconductors which furnish an occasional free electron for carrying current. Silicon and germanium are examples; they have about one free electron for every thousand atoms (as contrasted with copper, which has one



SIMPLE CIRCUIT uses transistor in place of three-element vacuum tube. When small signal passes over surface of transistor between cat's whiskers, larger current passed through transistor is modulated in replica of small.



ATOMS OF GERMANIUM, shown here in schematic crystal lattice, have four electrons *(black dots)* in outer orbits. These move freely into gaps in adjacent orbits.



ATOM OF PHOSPHORUS, introduced into germanium crystal, has one more outer electron. This is free to travel through the crystal, improving its conductivity.

for every atom). These semiconductors have long possessed a special interest for electronic researchers. The important fact about them is that the number of current-carrying electrons in them can be controlled. They can be made to act as conductors under some conditions and as insulators under others. Indeed, they are so sensitive that the current flowing in a semiconductor can be controlled by the brightness of a light shining on it in a region where a fine wire touches it. So this class of materials has been adapted to many uses. The crystal detector, used in early radios and now employed in an improved form in radar sets, is a semiconductor.

It was research into some of the mysterious electrical properties of semiconductors that led to the development of the transistor. It is helpful to try to visualize the electrical behavior of one of these substances. Picture a crystal of silicon (or germanium), which has four electrons in its outer shell—so-called valence electrons that hook the atoms together. Because they are fully occupied in forming bonds between the atoms, the electrons are not available for carrying electricity. Now suppose some impurity which has five valence electrons, say an atom of phosphorus, gets into the crystal. Four of these electrons become busy forming bonds with silicon atoms, but the fifth is free to carry current.

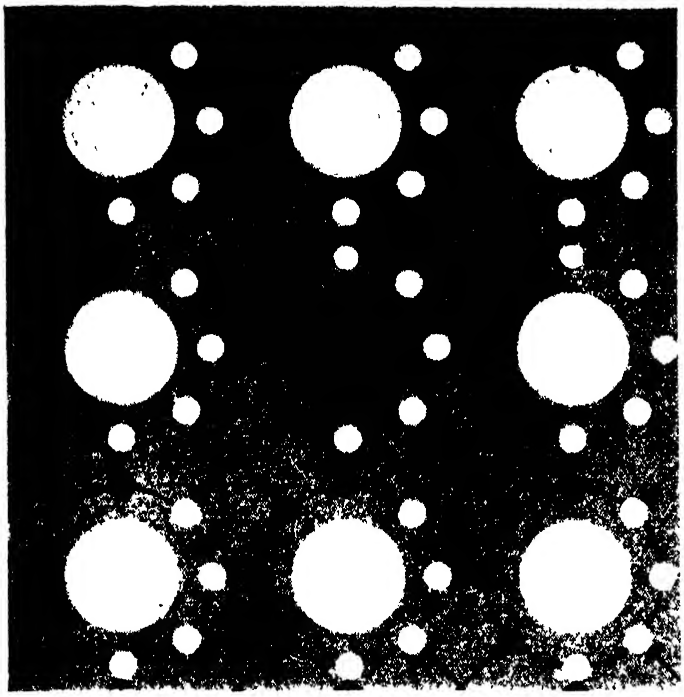
A more interesting case, and the one with which we are chiefly concerned here, is an impurity with three valence electrons, such as boron. One of the bonds needed for union with the silicon atoms is missing. The result is a state of disequilibrium, as the physicists say; there is some shifting around of bonds, but however they arrange themselves there is bound to be a missing electron. Because it is much easier to consider the movements of the gap created by the single missing electron than to follow the movements of the numerous other electrons as they create and fill in gaps, the missing electron is treated as an actual physical entity, though it is called a "hole." It has all the properties of an electron, such as mass and charge, except that, being the absence of an electron, its charge is positive instead of negative.

This, then, is a rough picture of the theory: the ability of a crystal semiconductor to conduct electricity is due to the presence of impurities that free some of the electrons which would otherwise be occupied in linking atoms. But a physicist at the Bell Telephone Laboratories, John Bardeen, became curious about a phenomenon that seemed to leave a hole in the theory. When a semiconductor is placed between two metallic contacts in an electrical circuit, one of the contacts being the point of a fine wire and the other a metal block, the arrangement acts as a rectifier, in a manner somewhat similar to the electronic tube. The reason is that the point contact between the semiconductor and the cat's whisker has a lower resistance to electrical flow in one direction than in the other. This difference in resistance accounts for the rectifying action of a crystal. Because it passes current predominantly in the direction of low resistance, the alternating voltage is converted to direct current.

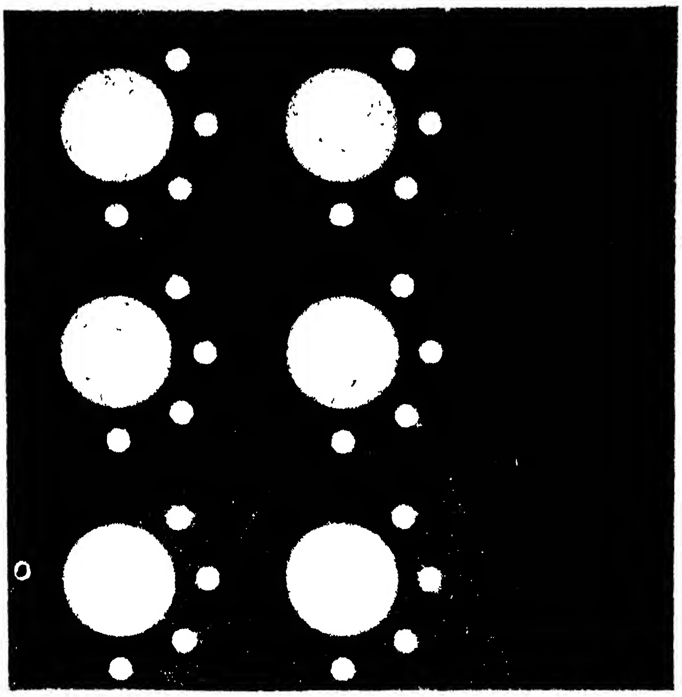
One would suppose that the respective resistances to current flow in one direction or the other would vary with the physical properties or resistance of the materials forming the contacts. But experiments showed that the properties of the metals made much less difference than the theory had predicted. Bardeen decided that something must take place at the surface of the crystal that the theory had not explained. Aided by previous work on a similar problem by William Shockley, director of the semiconductor research at Bell Labs, Bardeen undertook a theoretical study of the conditions at the surface of a semiconductor.

THE RESULT of this study was an important modification of the theory, which subsequent experiments were to prove correct. Bardeen reasoned that there were localized states on the surface of a semiconductor which differed from those in the interior. The number of such states, he said, was equal to the number of surface atoms. Like impurities in a crystal, these states produced holes capable of carrying current. These holes consisted of spaces on the exposed side of the atoms, which normally would be filled by electrons from adjacent atoms. This is an oversimplified picture of the theory, but it helps to make clear the essential concept: that the surface of a semiconductor is a better carrier of electricity than its interior. And Bardeen's theory satisfactorily accounted for the fact that the rectifying action of a crystal was independent of the particular metal used for the cat's whisker.

Shockley soon carried out an experiment that gave strong support to the theory. He reasoned that an externally



ATOM OF BORON, also introduced into germanium, has one less outer electron. This "hole" is able to migrate through crystal in much the same way as a real electron.



SURFACE ATOMS, one side of which does not adjoin other atoms, have unfilled holes. These make surface of crystal a conductor of tiny currents that pass across it.

applied electric field should increase the conductivity of a crystal by inducing electrons out of the bonds. He placed a sheet of germanium in an intense electric field. The increase in conductivity of the germanium turned out to be less than the old theory predicted. But the measurements fitted in well with Bardeen's new theory. They could be explained by the assumption, suggested by his theory, that the conductive layer of electrons or holes on the surface of the germanium acted as a shield against penetration of the material by the electric field, just as metallic shields around parts of radio sets keep away stray electric fields.

Bardeen, Shockley and a colleague, W. H. Brattain, proceeded to further experiments and calculations, each new experiment resulting in refinements of the theory. They concluded that the superior conductivity of the surface layer of germanium in their experiments was accounted for chiefly by the presence of holes, and that these holes were produced not only by impurities and surface states but also by the current passing through the crystal.

These studies, indicating a method of controlling the electrons or holes in a crystal, led Bardeen and Brattain to the invention of the transistor. The device consists of two fine tungsten wires of which the tips, only two thousandths of an inch apart, rest on a germanium crystal soldered in turn to a metal disk. All these elements are housed in a metal cylinder which is connected electrically to the metal disk and crystal, thus forming the ground terminal. The cat's whisker wires are connected to pins that can be plugged into a socket (*see diagram on page 53*).

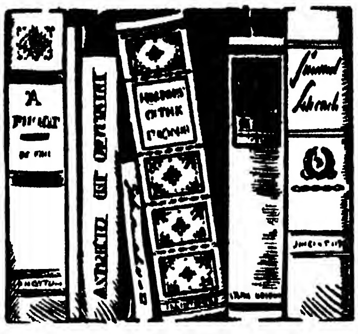
An electrical signal, modified by a small positive "bias" voltage to place it in the proper state for action on the crystal, is transmitted to the crystal by one of the cat's whiskers, called the emitter. The current releases holes in the surface layer of the crystal. The positive holes, flowing over the surface, are attracted to the second cat's whisker, which is biased negatively. The first whisker controls the number of holes flowing to the second whisker, in the same way that a vacuum tube grid controls the number of electrons flowing to the plate. The second whisker, called the collector, absorbs the current carried by the holes and passes on the signal, amplified 100 times. The amplification is partly due to the fact that a change in the incoming current to the crystal produces a greater change in the outgoing current. Most of it derives, however, from the great difference in resistance between the input and output ends of the circuit. The behavior of the electrons or holes is controlled in the crystal by superimposing variations on the positive and negative biased voltages applied to the emitter and collector. Thus the transistor is essentially a triode form of the well-known crystal diode detector used in radio.

Engineers at the Bell Laboratories have demonstrated that the transistor can be used as a voice amplifier, a television picture amplifier, a pulse amplifier and an oscillator. They have even produced a superheterodyne radio receiving set operating completely without vacuum tubes. Transistors were used in the set's amplifiers and in the local oscillator; conventional germanium crystal detectors served as mixer and detector, and selenium rectifiers were used in the power supply. This set performed as well as a conventional five-tube superheterodyne receiver. Since there are no vacuum tubes to heat up, a program comes in at full strength as soon as the set is switched on.

This instant response of the transistor is especially useful in pulse-type communication systems and in electronic computers. The transistor will also have a special value in electronic equipment that must operate continuously even when there are power failures. Such equipment, which includes telephone repeaters, fire and burglar alarms and the like, is generally equipped with batteries for an emergency power supply. The small power requirements of the transistor will make it possible to use batteries for a prolonged period.

YET all these applications are less important than the fundamental new knowledge that has been gained about the structure and energy states of solid matter and the electrical behavior of the surface atoms in a semiconductor. Basic study of these phenomena has been undertaken not only at Bell Labs but at Purdue University, the University of Pennsylvania and the Radiation Laboratory at the Massachusetts Institute of Technology. The holes in the crystal lattice of atoms obviously are a promising subject for further investigation.

Frank H. Rockett is an electrical engineer and associate editor of the journal Electronics.



BOOKS

"Grass," ninth Yearbook of Department of Agriculture, complete summary of the

by W. R. Chapline

THE BIGGEST crop produced in the U. S. is not wheat, corn or any other grain. The biggest crop is grass. Some 60 per cent of the nation's land is grassland, and this acreage is in many respects the foundation of our agriculture. Its yield is reckoned in terms of milk, meat, wool, hides and other livestock products; its importance as a crop may be measured in part by the present high prices of those products. In addition, grass serves many other indispensable functions —as a conserver of soil and moisture, as a habitat for wildlife, as a cover for playing fields, airfields and the like, as a decorative element in lawns.

Thus our 1,126 million acres of grassland, of which 109 million acres are under active cultivation as pasture, constitute one of our greatest agricultural assets, and their scientific management is certainly one of our prime problems. The fascinating subject of grass has finally been given the attention it deserves in the Yearbook of Agriculture for 1948. Prepared by more than 140 scientists of the U. S. Department of Agriculture, state agricultural experiment stations and other agencies, this volume, entitled *Grass*, is the most authoritative summary of grassland agriculture ever undertaken.

Botanically, the great food crops such as wheat, corn, rice and sugar cane are all grasses, but the major concern of this study is the forage grasses, the legumes, such as clovers and alfalfa, and other pasture, hay and range plants. The breeding, cultivation and proper grazing of these plants, laymen may be surprised to learn, is a highly developed art.

Grass was the basis for the pioneering settlement of the continental U. S. It nurtured the milk cows and other livestock of the settlers while they were developing a crop agriculture. During the past 50 years, however, grassland agriculture has advanced from the trial-and-error stage to a science based on tested knowledge.

The best results, of course, have been attained on the 109 million acres of cultivated pastures (often called "tame" pastures), which are located largely in the humid eastern half of the country, in the Pacific Northwest beyond the Cascade Range and on irrigated lands in

SMOOTH BROME is a long-lived grass imported from Europe in 1884.

TIMOTHY, long cultivated in U. S., is adapted to cool, humid conditions.

the West. These pastures furnish more than one third of the feed requirements of the nation's dairy cattle, a considerable part of the feed for beef cattle, sheep, horses and mules in the Corn Belt and the South, and essential parts of the nutrition of hogs and poultry in many areas.

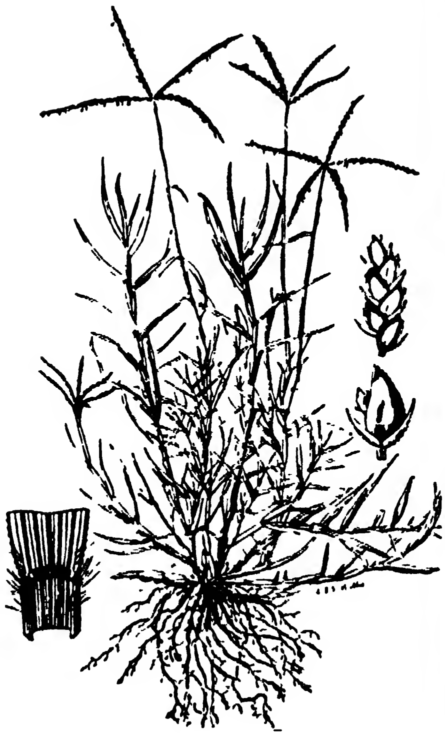
The principal aim of pasture management is to get the highest possible yield of digestible nutrients at the lowest possible cost. This aim may be accomplished by sowing grasses alone, or legumes alone, or a combination of the two, the best formula depending in each case on the kind of soil and moisture conditions. Usually a mixture of grasses and legumes is more productive than one kind alone. Modern herdsmen, far from taking what nature provides, have found that it pays to plant superior varieties or strains of grasses specifically suited to their land. Indeed, almost all good pasture plants are importations; the famed "Kentucky" bluegrass, for example, was originally native to Europe.

FURTHERMORE, scientific grass farming does not end with the proper selection of plants; fully as important is the timing of their use. Pasture plants should be eaten when they are succulent and immature, for they are then at their peak of digestibility and nutritiousness. As plants mature, their percentage of protein and vitamins decreases, crude fiber increases, and their nutritive value declines. Permanent pastures, therefore, normally should be most heavily grazed in the spring (which, incidentally, encourages the growth of legumes). They must not be grazed too early in the spring or too late in the fall, too heavily in dry periods or too lightly in wet. They must have periodic rest periods for recovery; most species of grass, particularly the tall-growing kinds, will not survive continuous heavy grazing. To rest their permanent pastures, scientific farmers maintain temporary or annual pastures, often in fields where they rotate with other crops. These serve to tide their livestock over dry periods and to extend the grazing season.

Nearly all pasture soils in the humid sections of the U. S., especially in the South, are deficient in calcium, phosphorus, potassium and nitrogen. Consequently good pasture management requires the use of fertilizers, manure and lime (except that where legumes are mixed with grasses, nitrogen fertilizer is seldom needed, for the legumes supply nitrogen). Pastures on irrigated lands demand even greater care—special preparation of the soil, proper drainage, control of salt or alkali.

On these and many other problems of pasture management, *Grass* is packed with helpful guidance. It advises farmers and ranchmen on how to renovate worn pastures, on the desirability of mowing brush and weeds to improve grazing capacity, on alternating grass with soil-depleting crops, on the best seeding mixtures. The Yearbook devotes considerable attention to hay, a crop so vital to the U. S. agricultural economy that 74 million acres of farm land are given to it. As the Yearbook points out, stored hay, silage and other roughage, although more expensive

ORCHARDGRASS is somewhat hardier than smooth brome or timothy.



BERMUDA-GRASS, imported from tropics, does well in southern areas.

KENTUCKY BLUEGRASS is grown in U. S. for pasturage, hay and lawns.

WESTERN WHEATGRASS is hardy U. S. species used in reclamation.

as feed than pasture grazing, are essential for wintering of livestock and as a supplement to range or pasture feeding.

AN ENTIRELY different problem, appealing even more to the imagination and to ingenuity, is presented by the vast ranges which constitute the major part of our grasslands. The 950 million acres of range lands in the U. S., of which about one-third are publicly owned (mainly in national forests and grazing districts), largely support some 75 per cent of the nation's sheep and goats, more than half of its beef cattle and substantial proportions of its other livestock. Range forage, consisting mainly of native plants, is less productive per acre than cultivated pastures, but it is cheap and, if not overgrazed, self-renewing. On western ranges, where annual rainfall generally averages less than 15 inches, the principal forage plants are bunchgrasses that do not form a sod, succulent range weeds and foliage and tender twigs of shrubs. During the past 15 years or so promising progress has been made in re-seeding range lands with species of grasses that do well on dry soils. The most widely used so far has been crested wheatgrass, seed for which has been readily available, but research has also found other grasses that appear even more promising. On moister soils, smooth brome and orchardgrass have done well and have proved more productive than either crested wheatgrass or native plants. Studies have shown that many worn-out range lands, which would take 30 to 50 years to recover naturally, can be restored within one to three years by seeding. Already more than five million acres of depleted western range lands and abandoned cultivated fields have been seeded successfully at reasonable cost. The seedings have increased forage production by 5, 10, sometimes as much as 20 times.

The paramount problem on the ranges is to avoid too heavy foraging. Unlike pasture turfs, the thinner bunchgrasses on arid and semi-arid lands cannot withstand close grazing. Unfortunately many stockmen have not been too well aware of this, and in times past they have used their ranges far beyond capacity. In addition, large submarginal areas in the West have been plowed for wheat and other crops and then abandoned. The result is that much of the western range is now low in productivity. Palatable plants have been replaced by thinner stands of unpalatable ones: tough shrubs and exotic annual weeds have crept in; to make matters worse, fertile topsoil, lacking adequate cover, has eroded away in many places.

Today a wide program for conserving and improving the range lands is under way. Annual opening and closing dates which harmonize with plant and livestock needs are being used. Systems of deferred and rotation grazing have been adopted. Sheep and goats are fed in open herds instead of close-packed ones and bedded down in a new place every night to avoid trampling of grasses and localized overgrazing. By strategic placement of watering facilities and better salting methods cattle are more efficiently distributed over the range. Poisonous plants are eradicated or controlled to prevent loss of animals.

The basic resource of grassland agriculture, of course, is the soil. Upon its maintenance and improvement depend the

REED CANARYGRASS was given name because seed is fed canaries.

CANADA WILD-RYE is most plentiful in Great Plains and Northwest.

future stability and permanence of pasture and range livestock production and of agriculture in general. And for stabilization of the soil, grasses fill the bill admirably under most conditions. They are especially valuable for controlling water erosion on sloping lands. When alternated with clean-cultivated crops, they not only protect but improve the soil. Indeed, on slopes subject to severe erosion it is far wiser in the long run to replace cultivated crops with pasture.

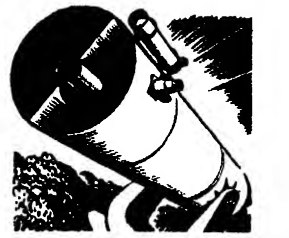
Grassland agriculture is a much younger science than the cultivation of the major crops. Important progress has already been made, however, not only in range and pasture management but in the breeding and improvement of forage plants. Research done so far indicates that there are great possibilities for further development of grass plants which will be more palatable, more nutritious, more productive and more resistant to disease and insects. The Yearbook *Grass* treats the whole subject comprehensively and in detail, and it is well illustrated with charts, drawings and photographs, some of them in color. Written with a minimum of technical exposition, it presents its subject in a simple, clear, terse manner, which should make it of interest to both laymen and scientists.

Grass is the ninth in the series of monographic yearbooks by the U. S. Department of Agriculture. The Department initiated this series, each devoted to some major phase of agriculture, in 1936. The first book, which covered the creative development of new forms of life through plant and animal breeding, was received with such enthusiasm that a second volume to round out the subject of genetics was issued as the Yearbook of Agriculture 1937. These two books presented reports of the Committee on Genetics appointed by the Secretary of Agriculture in 1933. Since then, yearbook committees dealing with phases of science fundamental to agriculture have been formed to develop a set of reference volumes for modern farmers. Each committee has had the help of many scientists, in the government and outside of it.

Soils and Men, the Yearbook of 1938, examined the soil problem from every possible angle. *Food and Life*, the Yearbook of 1939, was a comprehensive survey of the nutrition of domestic animals and human beings. In 1940 the economic and social aspects of agriculture were considered in a Yearbook called *Farmers in a Changing World*. In 1941 *Climate and Man* discussed weather as it affects agriculture. The 1942 Yearbook, *Keeping Livestock Healthy*, was a timely treatise on a major wartime problem. The great developments in agricultural research that came during the war were reported in one comprehensive volume, the Yearbook for the years 1943-1947, *Science in Farming*.

Grass, the present volume, is one of the most effective in the entire series. Like many other simple subjects of the earth, which are so basic and common that the human race incuriously takes them for granted, the story of grass is important and even exciting.

W. R. Chapline is chief of the Division of Range Research in the Department of Agriculture's Forest Service.



THE AMATEUR

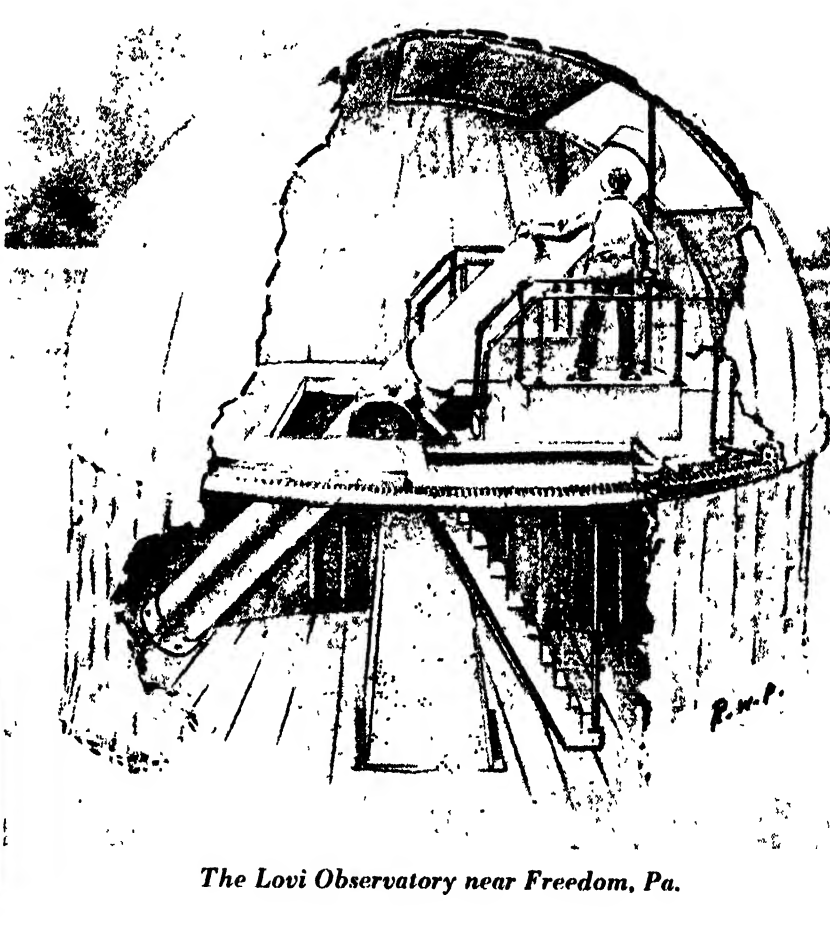
Conducted by Albert G. Ingalls

THOSE who become interested in amateur telescope making often note that most telescopes made by amateurs have tubes about eight times as long as their diameters. It is also interesting to observe that a few are only half that long, and that a few more are twice that long. No mere whim determines these proportions. Each has its functional significance. The uncommonly short telescope is a specialized type for viewing nebulae and the Milky Way, *i.e.*, faint objects. The unusually long one is a special type for viewing the planets and the moon, or extended and relatively bright objects. The commonest telescope, proportioned one to eight (f 8) is a compromise type serving both of these uses reasonably well.

The short telescope is especially designed for light-gathering. Its deeply concave mirror focuses light on a comparatively small area, giving a small image Therefore such a telescope, though it gathers much light, magnifies little. However, in observing stars magnification is not the great thing the novice often thinks it is. Other things are more important.

The long telescope specializes in magnification, something it can well afford since the planets send it enough light to permit that luxury (magnification greatly diminishes image brightness). In observing the planets, magnification is important up to a point past which it gives no gain and is called "empty" magnification.

When a beginner has made a six-inch and perhaps an eight-inch or ten-inch telescope of the common f 8 compromise type and thus has learned the basic shop practice of glass-working, he becomes one of the *cognoscenti*, if not one of the *illuminati*. He should then promote himself to the exalted status of an advanced amateur and go ahead with some less orthodox projects in optics. One such adventure is to make a telescope of the short or nebula-Milky Way type called the "RFT" (richest-field telescope) and described in *Amateur Telescope Making—Advanced*. Another is to complement it with a long planetary type. Each of these will be superior to the medium or compromise type for their specialized applications. Many amateurs do this.



The Lovi Observatory near Freedom, Pa.

ASTRONOMER

The same program could, of course, be followed without the preliminary steps. But only the incautious will attempt it, especially because the short-focus mirror of the RFT is much more difficult to make than mirrors of longer focus. (Incidentally, the best RFT of a reflecting type is no longer a four-inch f 4, but a seven-inch f 4.2 using a 1.2-inch eyepiece—a change made by Walkden in 1946 based on newer astronomical data.)

A 12½-inch planetary telescope, its tube perhaps 16 feet in length, would be something to dream about. Such a tall telescope poses some serious practical problems, however. The observer's head would have to be 16 feet above floor level and he would need some kind of structure to stand on. That structure, unless pretty bulky in itself, might prove somewhat unsafe. Last year Dr. Alfred Joy of Mount Wilson, preoccupied with observations with the 100-inch telescope, fell 20 feet to a concrete floor and broke three limbs.

John and Samuel Graf, father and son, farmers of Freedom, Beaver County, Pa., have solved this height problem in a unique manner. They permanently raised their whole observing floor to the middle of the telescope tube and then, for additional convenience, made the floor an integral part of their revolving dome.

As shown in Russell Porter's drawing from Samuel Graf's sketch, a stairway is suspended from the platform and does not quite reach the lower floor. The stairway rotates with the platform, so the lower story of the observatory is left empty. "This arrangement," Porter comments, "seems to me a fine and new contribution to the long-focus telescope. Everything except the telescope and its mounting is hung from the dome"

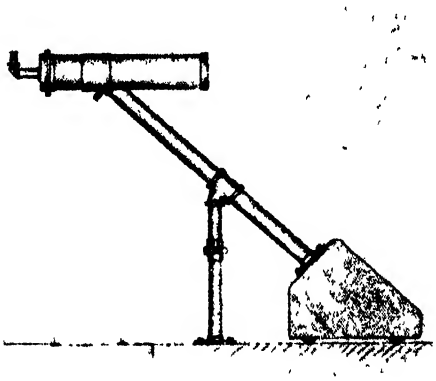
Other information about the Graf telescope has been supplied by Leo J. Scanlon of Pittsburgh, one of a neighborhood group (Scanlon, Norbert Schell, Roelof Weertman) who often visit the Grafs at their "Lovi Observatory." The 12½-inch mirror is 14 feet, 7 inches in focal length and is therefore an f 14. The welded 11-gauge steel tube weighs nearly 300 pounds. The dome is made of aluminum T ribs with 22-gauge aluminum sheets curved and riveted over them. The slot is a full four feet wide which, on the 17-foot diameter of the dome, gives ample slot width.

The dome shutter, as shown in the photograph, consists of three separate sections of hard aluminum, each of which can be independently moved from the horizon to past the zenith or set with narrow intermediate openings as desired, a feature essentially the same as that in the dome of

the 200-inch telescope on Palomar Mountain. This keeps out the draft.

To rotate the dome, a hand crank mounted on the platform, and therefore always easy to find in the dark, drives a sprocket that travels on top of an endless link sprocket chain attached to the dome ring plate. A section of the solid oak ring plate is a full 2 inches by 12. When the Grafs needed wide planks from which to cut curved segments they went to their own woods and sawed up a 225-year-old oak tree. This and other oaks furnished the observatory framing and side slabs. Scanlon claims that this makes the Graf's Lovi Observatory the oldest in the Western Hemisphere.

THE principal point in favor of the telescope mounting shown in a sketch by Robert D. Schaldach of West Hartford, Vt., is that there is nothing underfoot to trip over or even to bother not to trip over. It is also a clean, trim, simple, inexpensive and easy mounting to make. Its designer, son of a well-known sporting artist, writes the following:



The Schaldach mounting

"The long overhang of this mounting enables the observer to get completely away from the pier of the instrument, thus affording more freedom when observing, and especially when making drawings of things observed. It is true that the mass of it is to the south of the telescope but since at least three fourths of the observations made with small telescopes are in or about the ecliptic, it follows that little inconvenience will result.

"An additional advantage of this type of mounting is that there is no necessity for changing the telescope from one side of the pier to the other when making long observations that pass the zenith; no matter how it is turned, the tube cannot bump into the pier.

"All that is needed to make this mounting, except the headstock, is some three-inch pipe, two-inch pipe, a few fittings including a union, concrete, six bottles of beer and a little patience. The purpose of the union joint in the vertical strut is to make precise adjustment for latitude."

Schaldach credits an old illustration of a Potsdam astrographic mounting for his

inspiration, but does not his solution deserve the name "Schaldach"?

Shown the above description, N. J. Schell of Beaver Falls, Pa., commented: "My experience dictates the suggestion that, to avoid jars, the platform slab on which the concrete anchor weight rests should not be extended under the observer's position."

HOW BIG a secondary mirror should be used in a Cassegrainian telescope and, if a tertiary mirror is also used, just what should be the correct diameter of the latter?

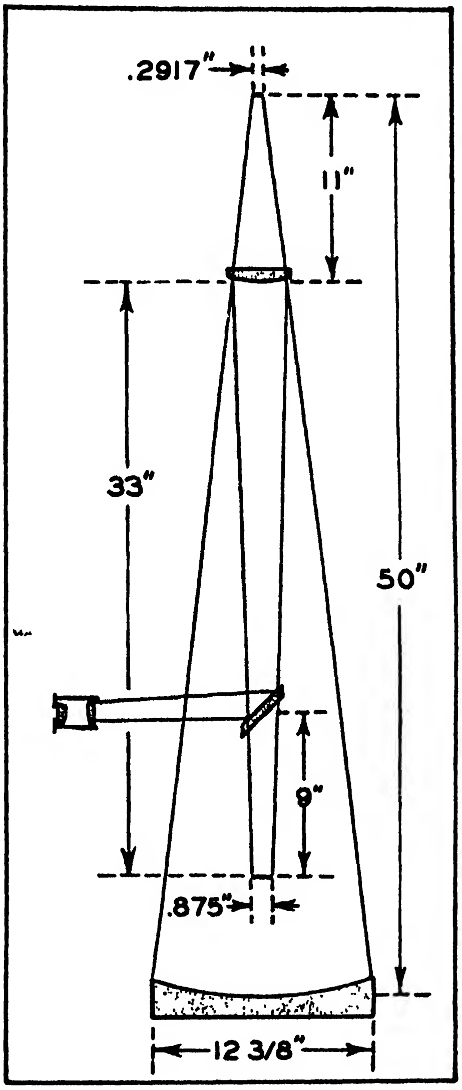
For an answer to this question, asked by C. R. Hartshorn of 1244 West 109 Place, Los Angeles, Calif., one instinctively turns to *Amateur Telescope Making*, pages 381 and 216, where the sizes of secondaries and layouts for Cassegrainians are discussed. There one finds no explicit answer to this uncommon problem. Hartshorn, however, now gives the answer, which isn't quite what might be expected.

"As an example," he says, "take the Cassegrainian shown, which happens to be my own. Suppose the eyepiece is a Ramsden with a ⅞-inch (0.875-inch) field stop and that the tertiary diagonal is nine inches inside focus, hence 24 inches from the secondary mirror. Now you might suppose that since the secondary cone of light is three times magnified (11 inches to 33 inches), it therefore would be the same as the tip of the cone from a primary of 12⅜-inch aperture and 150-inch focal length. You therefore might calculate your tertiary diagonal size on that premise. Thus: 12.375 minus 0.875 leaves 11.500 and this, multiplied by 9/150, gives 0.69 inch. Adding to this 0.875, the result would be 1.565 inch, which would appear to be the minimum size of the tertiary diagonal mirror along its minor axis. (The major axis would be 1.41 times larger.)

"However, I think this would be wrong. Should it not be calculated this way? The image that is to be examined at the secondary focus is ⅞ inch in diameter but the primary image of the same field, before the three times magnification, is only ⅞ divided by 3, or 0.2917 inch, in diameter. Therefore the minimum size of secondary is calculated thus: 12.375 minus 0.2917 leaves 12.0833 inches; and this, multiplied by 9/33, gives 0.5659 inch. Adding to this 0.875, the result is 1.44 inch, and not, as before, 1.565 inch, the minimum size of minor axis of the tertiary flat.

"It now will be seen that the last determination for the flat is 0.12 inch, or about an eighth of an inch, smaller than the first. If larger eyepieces are used in the same calculations the difference becomes even greater. This little difference is important because in this style of Cassegrainian telescope the edge of the diagonal acts as a diaphragm or stop to cut out part of the front light and this helps to give a darker field. Also the same concept—that of the 0.2917-inch primary image relative to the 0.875-inch final image—is useful in determining the size of secondary mirror for any Cassegrainian.

"The first method of calculation, the one which assumes the secondary cone to be the same as the tip of the cone from a long-focus Newtonian and which I am trying to prove wrong for that purpose, would be right if we were to confine our field to a point on the axis. This is because no amplification takes place in that special case;



The Cassegrain mirror problem

we do not amplify a point. The first method (assuming a 150-inch Newtonian) figures out thus: 12.375 times 9/150 is 0.7425 inch, the minimum size of flat needed to handle a point on the axis. Next, 2.7225 times 9/33 equals 0.7425, the minimum size of flat—either way works for this one case.

"But the point I have in mind is that when designing any compound telescope using either a secondary mirror or a Barlow lens, one should take into consideration that only a small primary image needs to be postulated in determining the size of the secondary, or the secondary and tertiary, which is to reflect or transmit the amplified secondary image to a given eyepiece. This idea is probably not new, yet I've seen nothing on it in print."

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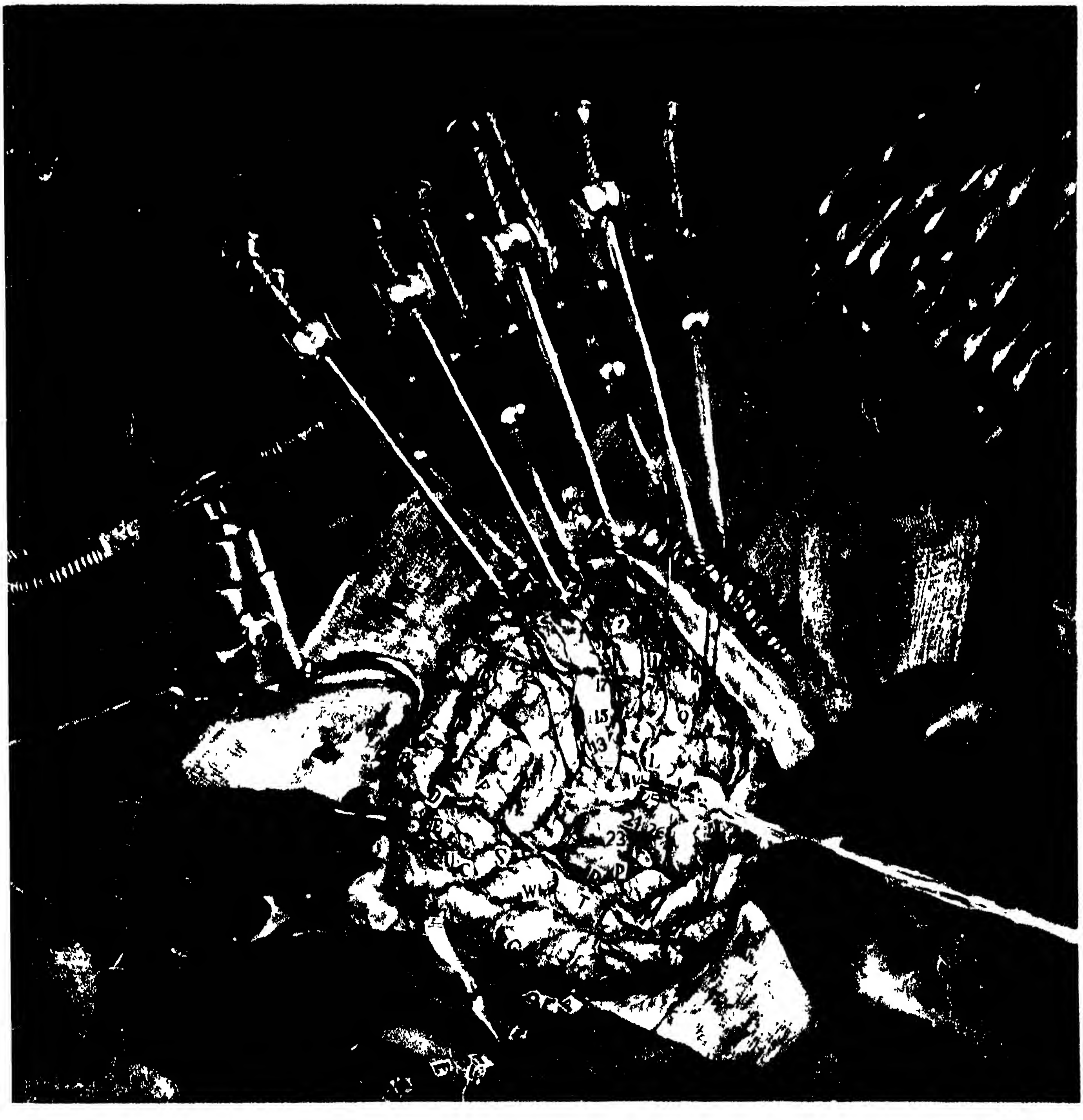
SURFACE STATES AND RECTIFICATION AT A METAL SEMI-CONDUCTOR CONTACT. John Bardeen in *Physical Review,* Vol. 71, No. 10, pages 717-727; 1947.

SCIENTIFIC AMERICAN



LOCATING BRAIN FUNCTION

FIFTY CENTS

October 1948

Shorty Sherock, orchestra leader, of Chicago, Illinois, had cancer of the lip—in 1936.

Mrs. John Stapel, housewife, of Columbia, Missouri, had breast cancer—in 1943

Milo Boulton, radio and television artist, of New York, had skin cancer—in 1944.

The Wonderful Story of the Stitch in Time that Saved Nine

Mrs. Lillian Maley, housewife, of Steubenville, Ohio, had cancer of the womb—in 1940.

Edward Reid, attorney, of Andalusia, Alabama, had intestinal cancer—in 1942.

Mrs Sara Pappas, housewife, of Birmingham, Alabama, had breast cancer—in 1940

George McCoog, schoolboy, of Paterson, New Jersey, had cancer of the thigh—in 1938

Mrs George Hall, housewife, of Havre, Montana, had skin cancer—in 1938.

Verna Duncan, schoolgirl, of La Grange, Georgia, had cancer of the neck—in 1937.

Each of the nine people you see here *had* cancer. They are typical of thousands who recognized one of cancer's danger signals *and did something about it*—living proof that cancer can be curbed if discovered early and treated promptly.

Cancer's danger signals can be readily recognized. If you think you have cancer, visit your doctor at once. Prompt action can return a priceless dividend --years of happy, healthy living to come.

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1. Any sore that does not heal, particularly about the tongue, mouth or lips.
2. A painless lump or thickening, especially in the breast, lip or tongue.
3. Bloody discharge from the nipple or irregular bleeding from any of the natural body openings.
4. Any change in the color or size of a wart or mole.
5. Persistent indigestion.
6. Persistent hoarseness, unexplained cough, or difficulty in swallowing.
7. Any change in the normal bowel habits.

LETTERS

Sirs:

You will be interested to know that the illustration on page 53 of the August number of *Scientific American*, comparing the interference fringes of natural mercury and artificial mercury 198, has been awarded first prize in the International Photography-in-Science Salon at the Smithsonian Institution.

WILLIAM F. MEGGERS

National Bureau of Standards
Washington, D. C.

●

Sirs:

In the letters department of your July issue I find a scientific horror that deserves a place of high dishonor. L. A. Hausman of the New Jersey College for Women writes to warn you against again becoming "too metallurgical, commercial." Is it not enough that Dr. Hausman, zoologist, uses the words metallurgical and commercial as synonyms? Must he also congratulate the editors on ignoring things metallurgical? Certainly he is not being very helpful in your efforts to add the metallurgists to your subscription list.

I shall freely admit that metallurgy is one of the most ancient of arts, and also that it is currently one of the largest industries. It is also true that numerous clever salesmen and several competent blacksmiths have at one time and another been dignified by the designation of metallurgist. Dr. Hausman will doubtless congratulate himself that the "purity" of his science has not been contaminated in this manner, since zoology is neither ancient, overgrown, highly profitable, nor attractive to untrained practitioners of the useful arts. Certainly one does not become a consulting ornithologist for commercial reasons.

It is impossible for me to speak with any authority regarding Dr. Hausman's subject, but is it perhaps possible that the science of zoology also remains uncontaminated by close relations with chemistry, physics and mathematics? If so, the professor must certainly be excused for not realizing that the science of metallurgy is one of the two applied sciences having the broadest range of interest. He cannot be expected to know that metallurgy is the most complex of the applied sciences, and the one which most rapidly submits the theories of the basic sciences to the test of agreement with the behavior of real materials. Should a "pure" scientist know:

That the latest theoretical developments of physical chemistry have within the last five years explained the reactions in an iron blast furnace sufficiently to allow this furnace to be redesigned for efficient operation;

That the same physical chemistry has furnished insufficient information to allow an understanding of the open hearth furnace and Bessemer converter for making steel, with the result that the despised metallurgist has perforce turned physical chemist to push back this boundary of a pure science;

That the metallurgist waits impatiently for the common chemist to find ways of preparing and purifying at least a dozen "new" metallic elements which the metallurgist already knows are superior to steel, aluminum or brass for many important purposes;

That all of the latest theories of experimental physics are insufficient to explain fully the fact that the strength of ordinary commercial metals is only one per cent of the value the physicist predicts after measuring the force between the atoms, and hence that the metallurgist is left to his own devices in trying to see if he can salvage a portion of the strength which might be present;

That every new metal or alloy prepared must be examined with X-rays to determine details of structure which are about 100 million times smaller than any detail that has ever been disclosed by X-raying an animal in the zoo, and that it takes the full power of the Einstein theory to calculate the equations controlling this examination now that physics has insistently informed us that X-rays are a stream of particles; and that even the famed calculating machine at Harvard cannot yet predict the full effect of adding traces of various elements to an alloy formula?

All this ignores the fact that the last war was certainly lost and won by metallurgists, frequently the ones driven from Central Europe by "social scientists" who didn't know how to keep them working happily. We can ignore the fact that long-range airplanes, high-power radar, and nuclear explosives waited for the solution of metallurgical problems, to say nothing of the metallurgy of guns, shells and bombs. Metallurgists are not proud of working overtime during the war to solve such problems, since we *should* have had the solutions ready in advance. Perhaps if some "pure" scientists are restrained from splitting hairs over the possibility of making a dollar or two, from demoting metallurgical science to the rank of commercial tinkering, and from scaring all of the bright young men entering college away from the "practical sciences" into such activities as working out the proper Latin names for new varieties of penguins, the metallurgists may be ready for the next great demand on their talents, whether this be the fabrication of non-radioactive arrowheads over backwoods campfires or building a ship to meet the demands of the First Interplanetary Expedition of the American Society of Zoologists.

GEORGE A. MOORE

Assistant Professor of Metallurgy
Department of Metallurgical Engineering
Towne Scientific School
University of Pennsylvania
Philadelphia, Pa.

● The editors of SCIENTIFIC AMERICAN doubt that Dr. Hausman intended any disparagement of the ancient and honorable science of metallurgy. The editors nevertheless wish to thank Dr. Moore for an eloquent definition of his profession and for an account of some interesting new researches.

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SCIENTIFIC AMERICAN

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

OCTOBER 1898. "In a fine work recently published in England, Prof. J. J. Thomson endeavors to demonstrate that various gases, submitted to an electric discharge in a Crookes tube, can be brought to such a state that the quantity of electricity carried off by each particle is constantly proportionate to the mass of each of the small projectiles that escape from the surface of the cathode. He concludes therefrom that all the gases with which his experiments were tried can be dissociated to such a degree that the ultimate particles thus obtained shall be identical with each other. According to this, we find realized for the first time the division of matter into its ultimate elements, which are found to be all alike, as a large number of scientists had already considered them to be. The reasoning seems to be infallible, and the result is one of the most wonderful that science has brought to light in recent years; and yet the memoir of the learned scientist has passed almost unnoticed. Are physicists in general ignorant of it, or are they waiting for a confirmation of its conclusions? But little has been said about it, and it seems that it is well for us to be reserved."

"The American Association for the Advancement of Science has now completed an existence of half a century. It has become one of the leading scientific institutions of this country. Since its organization, fifty years ago, the world has advanced with wonderful rapidity in all directions, and especially in the various fields of science. It is hardly too much to say that the scientific progress of the last half century far exceeds all that was done in the preceding thousand years. The life of this association practically covers the development and comparative perfection of many of the sciences."

"We do seem a trifle behind date in this country in the introduction of horseless carriages, when the fact is noted that at the recent exhibition in Paris no fewer than 750 automobile vehicles, of the carriage type, were shown, and that of these 120 were of the light chaise type, says the Electrical Engineer. It may be questioned whether 150 carriages, all told have yet been built here."

"A very interesting application of telegraphy, as carried out by means of Hertzian waves, has lately been tried in Dublin. During the races of the Royal Alfred Yacht Club the proprietors of the Dublin Daily Express were able to receive their dispatches by means of this system. Mr. Marconi, who conducted this operation, followed the racing yachts in a tugboat, in the cabin of which was the necessary apparatus used in transmitting the messages. The messages were received by a subordinate at Kingston, a distance of some five to ten miles from the point of transmission, and from there were telephoned to the journal. All the messages were received in the space of a few minutes after they were sent, and were published in subsequent issues of the paper."

"A remarkable balloon ascent occurred at the Crystal Palace, near London, on September 15, by Prof. Berson, of Berlin, and Mr. Spencer. The large balloon reached an altitude of more than five miles, the exact height being 27,500 feet. This altitude has been only once exceeded, and that was by Glaisher and Coxwell in 1862, when they ascended 37,000 feet. At 25,000 feet there was a decided feeling of dizziness and breathing became difficult. The aeronauts then began inhaling compressed oxygen. The thermometer showed 29 degrees below zero and the aeronauts shivered and trembled, though they were very warmly dressed."

"In a recent gathering of the British Association for the Advancement of Science, the inaugural address delivered by Sir William Crookes was of an unusually startling and in some respects sensational character. Choosing as his main theme the question of the world's food supply, he produced a formidable array of statistics regarding the present and probable future ratio between the supply and demand of the world's staple article of food—all tending to show that, before many decades are past, the demand for wheat will be far in excess of the earth's capacity to produce it."

OCTOBER 1848. "Professor Bond, of Cambridge, Mass., has discovered a new moon of Saturn. Its orbit is exterior to that of Titan. It is less bright than either of the two inner Satellites discovered by Sir William Herschel."

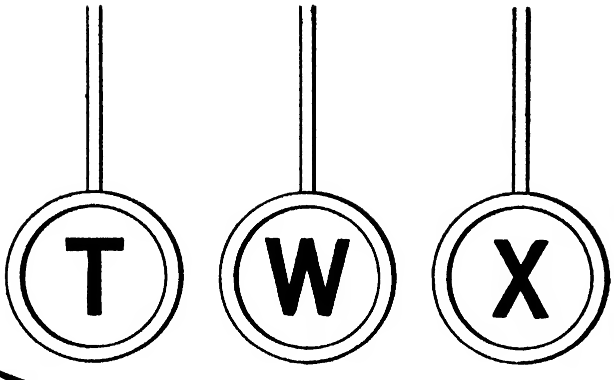
"It must be known to many of our readers that the ingenious Oliver Evans proposed to drive steam wagons over the roads in Pennsylvania. As yet, however, no practical test of this kind of Locomotion has been made in our country; in England it has, and would have been successful only it met with such opposition from the Turnpike trustees and from one unlucky accident that occurred on the road between Paisley and Glasgow in 1834, whereby a number of lives were lost.—The experiments made on the Paisley road in Scotland, were mechanically successful—the carriages went through the streets as if drawn by horses and up and down the hills likewise."

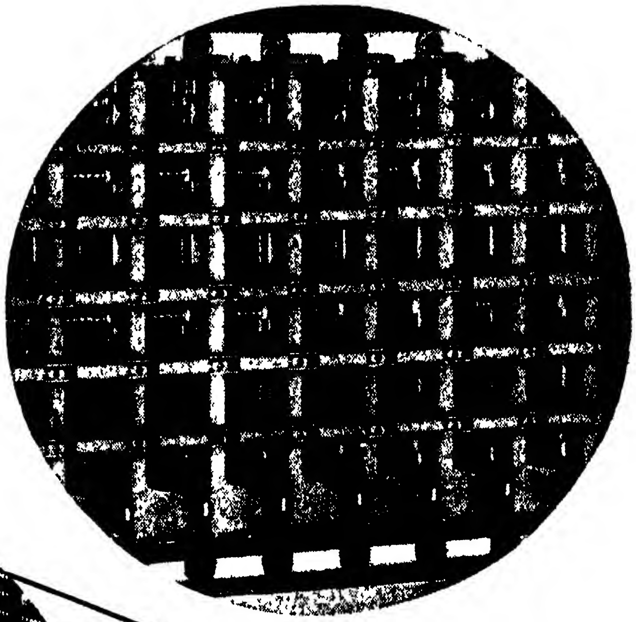
"A new barometer has lately been exhibited in London without the use of alcohol or mercury and which is said to be a simple, beautiful, and accurate indicator of atmospheric changes on an entirely novel principle. It is termed by the inventor, a French gentleman, the Aneroid Barometer."

"Recently in England, on the Great Western Railroad, seventy-seven miles were passed over by an express train in seventy-eight minutes twenty-nine seconds, including stoppage of five minutes thirty-five seconds. Fifty-three miles of the journey were performed in forty-nine minutes thirteen seconds. The speed in some cases was kept up at seventy, seventy-two and seventy-seven miles an hour."

"We see by a paragraph in the Boston Mail, that a course of medical instruction for females is about to commence in that city. This is said to be the first time in our country, that systematic instruction has been provided for females in this rich branch of practice. It is stated that there is in all directions, an urgent demand for qualified Midwives. In a number of places, money has been raised and committees appointed to select suitable females to receive instruction in this course.—Quite a number of pupils are already engaged."

"Dr. Randall, who was detached last June from Dr. Owen's Geological corps for the purpose of exploring the Des Moines river to its source, was lately robbed by the Sioux Indians of his purse, blankets, provisions, clothes, &c., and he had to travel a hundred miles or more on foot, from the source of the Des Moines to Prairie du Chien, in a very wretched condition. Dr. R. was also robbed of valuable geological specimens. He says of the country bordering upon the Des Moines: "Its agricultural beauty and capacity are unsurpassed, after leaving the settlements, and its geological resources are unequalled to support a dense population."





Switches in small offices do a distant operator's bidding.

IT TALKS WITH FINGERS

For those who want to talk, Bell Laboratories scientists developed the telephone. For those who prefer the typewritten message, they developed TWX — Teletypewriter Exchange Service.

Fingers on a keyboard send your message to be typed by one or scores of other teletypewriters selected at your request from the 21,000 instruments connected to the Bell System's nationwide TWX network.

As in telephone service, your TWX connection is set up through switching systems, manual or mechanical, as best may serve. And over long distances your message travels economically with many others on the same pair of wires. All these technics are products of Bell Telephone Laboratories research in the telephone art.

TWX is today a vital link in the nation's chain of communication. And year by year it benefits from the steady growth of the telephone system which carries it.

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EXPLORING AND INVENTING, DEVISING AND PERFECTING FOR CONTINUED IMPROVEMENTS AND ECONOMIES IN TELEPHONE SERVICE.

THE COVER

The painting on the cover shows the electrical exploration of brain areas for location of their specific functions *(see page 26)*. In this test, made at the Montreal Neurological Institute, the patient was operated on for a brain disorder, and neurologists used the opportunity to study his exposed brain. The instrument employed is an electrocorticograph, which by means of sensitive electrodes starts or records electrical impulses in the cortex. Letters represent sensory areas; when the patient is stimulated through one of his senses, an electrode records which part of the brain receives the message. Motor areas, represented by numbers, are located by the reverse process; the neurologist touches a point on the brain with an electric needle carrying a small current and observes the part of the body which responds. By moving the electrodes and exploring the surface with the needle, the experimenters are able accurately to define each region that is involved.

•

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

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SCIENTIFIC AMERICAN
Established 1845

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His chest was protected—*but*...

Drape-shape steel gave this well-dressed knight a certain amount of protection against stray missiles...

Yet he died, not in battle, but in bed... felled by a deadly dart 1/10,000th of an inch long—the *tubercle bacillus*.

He and millions of others through the ages never knew what hit them.

Today *we* know. But ignorance and indifference still account for most of the 50,000 people who are killed by tuberculosis each year.

The germ that steel couldn't stop certainly can't be thwarted by a business suit or a mink coat.

Modern science and medicine, however, *can* give you effective chest protection. A chest X-ray is a sure way to detect TB!

If you are harboring TB germs, an X-ray can "see" their destructive effects long before you feel sick. If proper treatment is started in the early stages, the cure is comparatively easy.

The later TB is found, the longer, harder, and costlier will be the cure.

Remember, too, that TB is contagious. A person who has TB can spread it to other members of his family.

You can find out whether or not you have TB by having your chest X-rayed.

SO PLAY SAFE...

CHECK YOUR CHEST... *GET AN X-RAY TODAY!*

See your Doctor, Tuberculosis Association or Health Department

A PUBLIC SERVICE PROJECT

SCIENTIFIC
AMERICAN

OCTOBER 1948 VOL. 179, NO. 4

THE BINGHAM PLAN

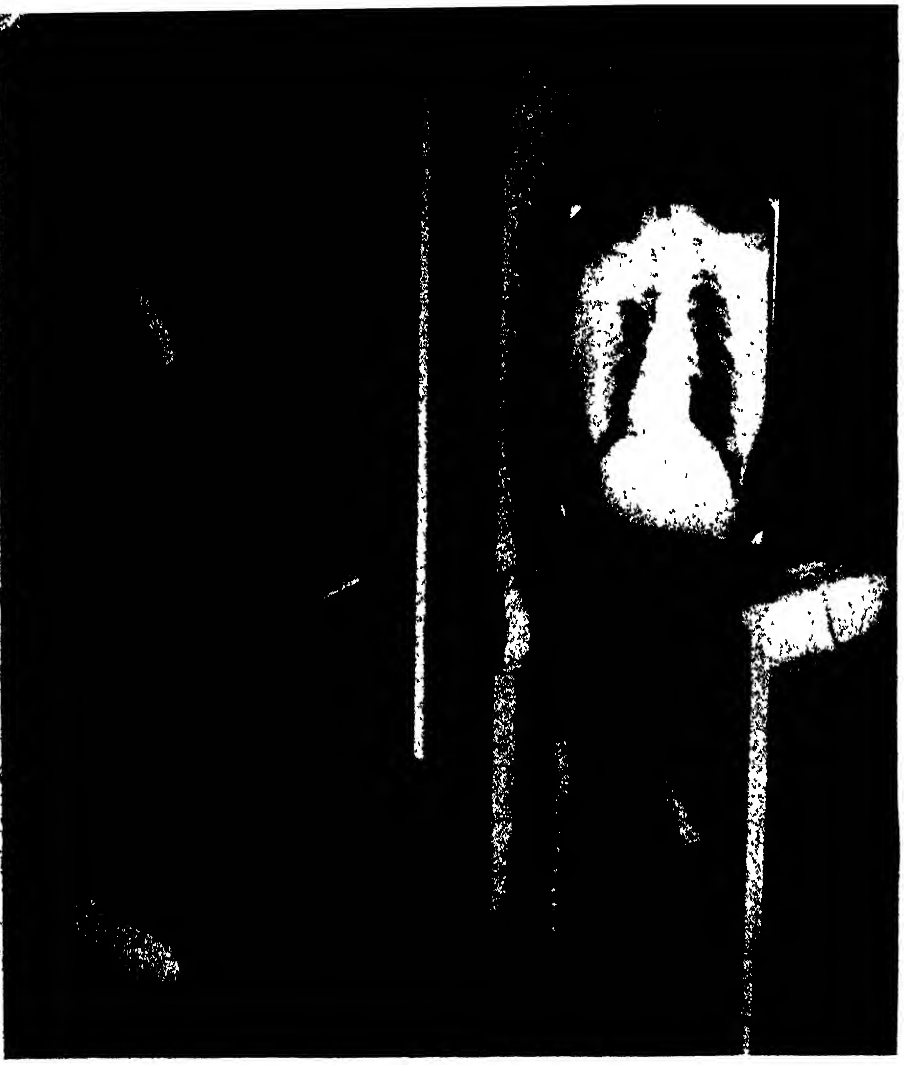
A little-known foundation in New England has achieved a practical solution to the problem of bringing hospital services to rural areas

by Leonard Engel

FOR a decade and a half a little-known foundation has been conducting an unusual experiment in hospital service for rural New England. The name of the enterprise is the Bingham Associates Fund. Its purpose is to develop a practical means of bringing the medical knowledge and the expensive facilities of a great medical center to country doctors and their patients. It has accomplished this purpose, at commendably low cost, by a scheme that links local, regional and metropolitan hospitals in one closely integrated system.

The hub of the Bingham system is the New England Medical Center, connected with the Medical School of Tufts College in Boston. The Medical Center reaches

COMMUNITY HOSPITAL at Castine, Maine, is one terminus of outgoing medical services and information under the Bingham plan. Shown on the steps are hospital's single physician, Dr. H. W. Babcock, and his staff.



AT COMMUNITY HOSPITAL in Castine, Dr. Babcock (*see photograph on preceding page*) examines chest X-ray of patient. When he wishes to submit X-ray for diagnosis of specialist, he mails it to regional hospital (*right*).

AT REGIONAL HOSPITAL in Lewiston, Maine, two roentgenologists examine plate sent in by Dr. Babcock.

out to some 30 small hospitals in the rural areas of Maine and western Massachusetts. The plan creates a highway for two-way medical traffic between the Center and the outpost hospitals. Up the highway, from local hospital to regional hospital to the center, moves a stream of patients, doctors' queries and specimens for laboratory analysis; at the center, the patients' ailments are diagnosed and doctors receive guidance concerning treatment. And in the opposite direction, from the teaching center outward to general practitioners in remote areas, flows a refreshing current of training and medical knowledge.

Because the Bingham plan deals directly with the fundamental problem of U. S. rural medicine—the lack of up-to-date hospital facilities and techniques, which in turn contributes to the shortage of physicians in rural areas—it is one of the most significant current experiments in American medicine, although one of the least publicized. Started on a tiny scale in one Maine town 16 years ago, the plan has grown to three regional groups covering a wide area, and the Bingham Associates are now considering the organization of an additional group. The Bingham example has inspired New York State to project a similar regional scheme in the construction of new hospitals. The Kellogg Foundation teaching projects in Michigan and in New York and the Commonwealth Fund regional hospital program in Rochester, N. Y., are all modeled on some of the regional features of the Bingham plan. The principle has also been endorsed by the U. S. Public Health Service, and a model regional plan has been prepared for the guidance of states in connection with the national hospital building program authorized by the new Hill-Burton Act.

The Act was itself a recognition of the serious national shortcoming which inspired the Bingham plan: the wide gap between the quality of medicine available to city people in the U. S. and that available to country people. The rural areas (including towns under 10,000 population), where three fifths of the nation's children are born and raised, are far behind the cities in quantity as well as quality of medical care. Rural families make substantially less use of hospitals than urban families. They have 20 per cent more serious disabling illness per capita (as measured in days lost per year). The death rate in towns of under 2,500 population is the nation's highest. By every index, the most urgent U. S. medical need is to improve the amount and quality of the service in small towns and farm areas.

THE Bingham program, financed by William Bingham II, of the Standard Oil family, originated in 1931 as a project to raise the community hospital in Rumford, Maine, to metropolitan standards. The Rumford project was to be a demonstration. It soon became clear, however, that the plan was unrealistic. To raise a small-town hospital to big-city standards involved outlays for facilities and services that a small hospital could not afford. A minimum of several hundred hospital beds is required, for example, to keep a full-time pathologist busy. A 50-bed hospital cannot support him and does not warrant his full-time services in any case, for the supply of pathologists is too limited. Nor can a small institution maintain diagnostic laboratories, fluoroscopy equipment, a teaching program, or the other essentials of a first-rank hospital. The Bingham pro-

If they wish to have it examined by others, the plate is mailed to the New England Medical Center in Boston.

AT NEW ENGLAND MEDICAL CENTER, headquarters of the medical services of the Bingham plan, Dr. Babcock's X-ray plate is inspected by a group of specialists. Plate and diagnosis are then sent back to Dr. Babcock.

gram therefore was soon revised. It was decided to make big-city facilities available to Rumford and other small towns by attaching their small community hospitals to a regional general hospital.

The new program was launched in 1935 with six community hospitals, ranging in size from 30 to 66 beds, affiliated with the 193-bed Central Maine General Hospital in Lewiston. Since then eight more community hospitals have been added to this group. The two other groups now in operation are in eastern Maine and in western Massachusetts. The former, composed of 13 outpost hospitals ranging in size from 12 to 58 beds, has as its regional hospital the 213-bed Eastern Maine General Hospital in Bangor. The western Massachusetts group, established in 1943 with funds from the Rockefeller Foundation, follows a somewhat different plan: there being no hospital of outstanding size in Massachusetts' Connecticut Valley towns, four intermediate hospitals (87 to 136 beds each) are serving jointly as the regional center for three outpost hospitals.

Through these groups the Bingham Fund has initiated an extensive program of activities. Among the first and most successful was the provision of laboratory services. A fully staffed and equipped laboratory was installed in each regional hospital. In addition, the pathology departments of Tufts Medical School and the Joseph H. Pratt Diagnostic Hospital, both of which are units of the New England Medical Center, were made available for consultation. To these laboratories, doctors in the community hospitals sent specimens for analysis by mail. Later, small chemistry and blood laboratories, each manned by a technician, were established in the outpost hospitals. Some hospitals were also fitted with equipment for making biopsies of frozen tissue in the diagnosis of cancer. At present, blood tests and routine chemical analyses are performed by the community hospital, and frozen sections are analyzed in the local operating room by the regional pathologist, who comes by appointment. Surgical and other specimens are sent to the regional laboratory and reports on them are delivered within 48 hours, or even less in emergencies. The advice of expert consultants in Boston on especially difficult specimens can be had in four or five days. Thus the Bingham community hospitals now have a range of laboratory services equaling that of any metropolitan hospital. The Lewiston regional hospital alone is making 8,000 tissue analyses a year—which in proportion to the number of beds compares favorably with the services available in big-city hospitals.

Similar services have been established in X-ray and cardiography. When the Bingham plan was started, scarcely any of the community hospitals now affiliated with it had X-ray equipment. The Bingham Fund offered to pay for the training of X-ray technicians for member hospitals willing to buy machines. Full-time radiologists also were available at the regional hospitals to read the plates. The plates were sent by mail or were examined by the radiologists during their weekly visits to the community hospitals. Sometimes they were studied in biweekly X-ray conferences at the regional hospitals for doctors from the outpost communities. In the Bangor group, the service is now carried on mainly by mail, because of the great distances and poor roads of northeastern Maine. In the Lewiston group, most of the community hospitals have half-time radiologists whom they share with neigh-

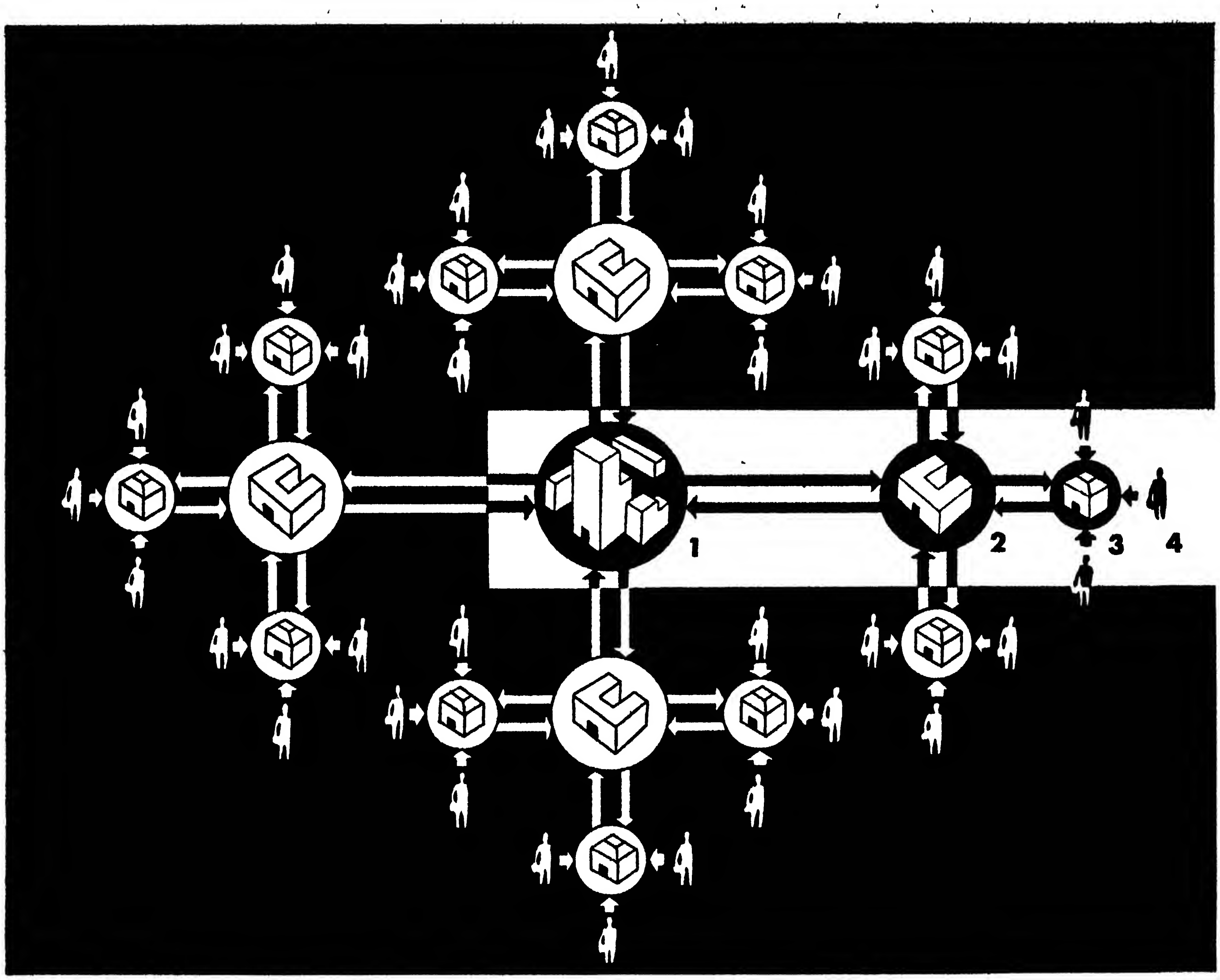


DIAGRAM outlines the principal elements of the Bingham plan. A sample route of communication among the elements is shown in blue. The base of the plan is the New England Medical Center (1). From it flow services to the regional hospital (2). Regional hospital then serves community hospital (3) and general practitioner (4).

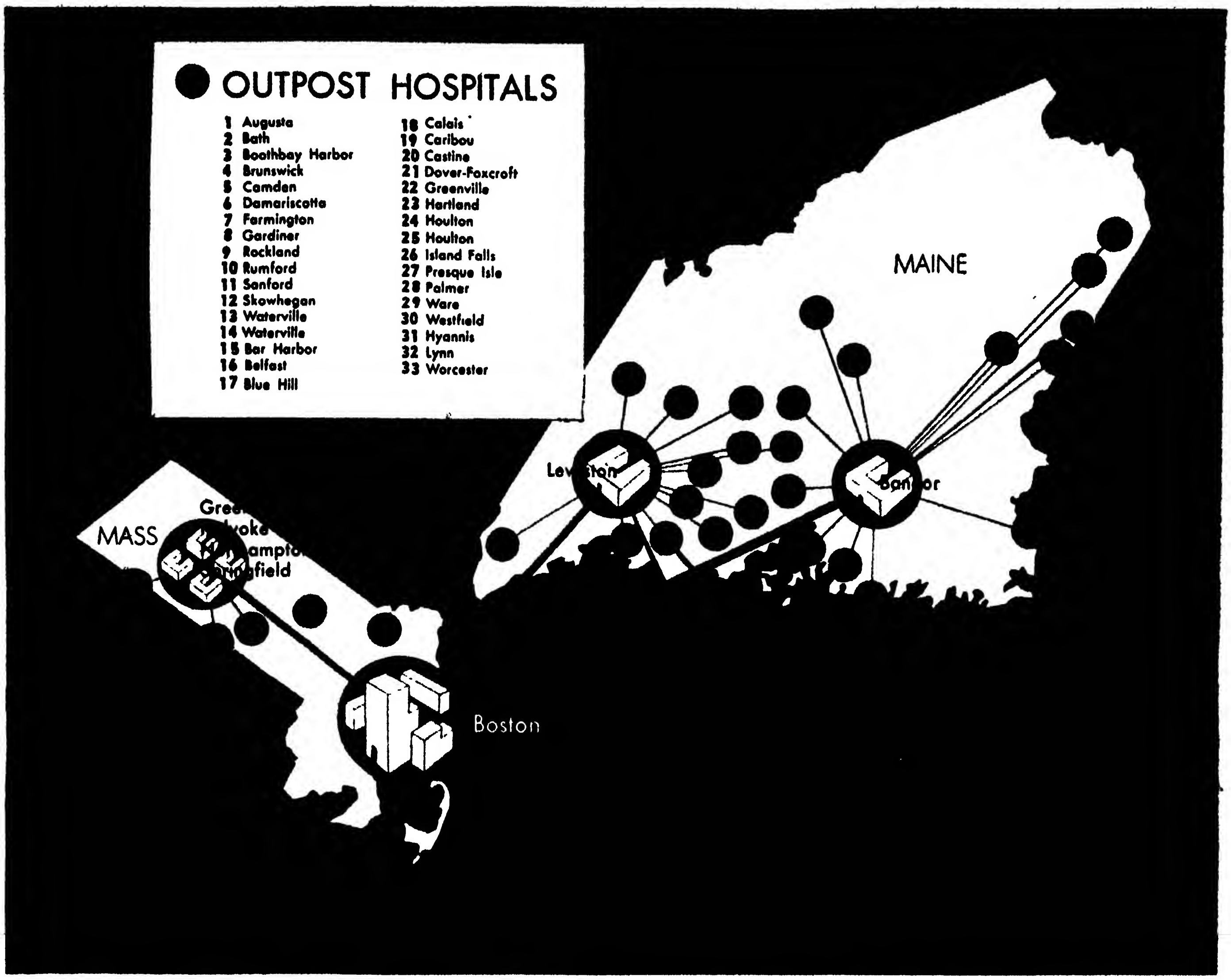
boring hospitals. The cardiographic service, also conducted by mail, provides interpretations by cardiologists at the regional hospitals of heart tracings sent in by local doctors. As in the case of laboratory specimens, especially difficult X-ray plates and cardiograms go to the Boston center for study by experts.

BESIDES services of this kind, which may be used for both office and hospital patients by doctors with privileges at participating hospitals, the Bingham program provides for a chain of diagnostic examinations of the patient himself. The patient may be sent from the community hospital to the regional hospital and then, if necessary, to the Pratt Diagnostic Hospital. The "Pratt," which is the largest hospital in the world devoted exclusively to diagnosis (it will lose that distinction when it opens a new surgical wing this fall), grew out of a proposal by the man for whom it is named, Dr. Joseph H. Pratt, one of the founders of the Bingham program. When rural patients are referred to metropolitan centers, usually they are sent for both diagnosis and treatment. Dr. Pratt suggested that they be referred for diagnosis only and that they then be returned to their home communities for treatment by local physicians. Twenty beds were therefore set aside in the Boston Dispensary, a Tufts-affiliated teaching hospital, to handle diagnostic cases referred from the community hospital at Rumford, Maine. Later, when the regional program got under way, the 90-bed diagnostic hospital was built. Patients are admitted to the Pratt only by referral, stay an average of only three days, then go home. Simultaneously the diagnosis and recommendations for treatment are sent to the referring physician.

What the Bingham program means in human terms to the rural residents in its area is illustrated by the following typical case. A general practitioner in rural western Massachusetts recently telephoned Dr. Roy Crosby, assistant to the medical director of the Pratt Hospital. One of his patients had complained for several months of severe headaches. The doctor was sure it was not migraine. "Have you examined the patient's eyes through an ophthalmoscope?" asked Dr. Crosby. The doctor had, and had found that the optic nerve was swollen. "Get the patient to a Boston hospital at once," advised Dr. Crosby. "It sounds like a brain tumor." The patient was rushed to Boston and a surgeon removed the tumor the same afternoon. Such teamwork between country doctors and city hospitals is of course not uncommon, but the Bingham plan establishes channels of communication that make it a matter of daily routine.

Such, in rough outline, is the Bingham program for direct services to patients. Its educational program for rural doctors is no less important, though in some respects it has been less successful.

This latter program is conducted both in Boston and in the field. Doctors and other medical personnel are brought to Boston at the expense of the Bingham Fund, for special training at the Tufts Medical College and other Boston medical schools and teaching hospitals. The Pratt Hospital also stages a round of clinical conferences every other Friday for Maine and western Massachusetts doctors. One of these conferences, conducted by Professor Merrill Sosman, the Harvard Medi-



MAP shows actual organization of the Bingham plan. Six regional hospitals (one in Lewiston, one in Bangor and a group of four in western Massachusetts) are attached to Medical Center in Boston. Outpost hospitals are attached to regional. In Massachusetts, where plan is incomplete, some deal directly with Medical Center.

cal School radiologist, is regarded as the "greatest show in Boston" and plays to capacity audiences.

At monthly intervals, specialists from Boston conduct rounds in the wards of the Lewiston, Bangor and western Massachusetts regional hospitals. In addition, teaching residents have been placed on the staffs of these hospitals to organize clinical conferences and, in collaboration with the staffs, to develop training programs for interns and residents

THE Bingham program trains hospital technicians as well as doctors. The Fund is currently sponsoring four schools of medical technology—one at Holyoke, one at Bangor and two at Lewiston. One of the Lewiston schools is a new departure in the training of medical technologists. It offers a one-year "assistant technologist" course of high-school grade (medical technology schools are usually of college grade). The school is intended to meet the outpost hospitals' pressing need for laboratory workers. It is open only to residents in the Bingham communities. They must take six months of practical training in a Bingham hospital and are expected to work in their home-town hospitals after graduation. The assistant technologists are not qualified for positions in a full-fledged diagnostic laboratory, but they are amply trained for the laboratory of a small hospital. Another new undertaking, which equally reflects the Bingham organization's readiness to shape its activities to changing needs, is a two-year-old program at the Lewiston regional hospital for training nurse-anesthetists.

The foundation has been less successful than it had hoped in getting rural doctors to take advantage of its educational offerings. Before the war a fair proportion of the doctors went to Boston every year for graduate courses, but few have resumed them since the end of the war. Nor do many rural doctors attend the ward rounds at the regional hospitals or the conferences at the Pratt Hospital. As a doctor in Aroostook County observed, "Most of us have been too busy with the postwar boom to bother much about education." The sponsors of the program are inclined to think that rural doctors probably cannot be reached effectively from Boston and that teaching them is properly the business of the regional hospitals, which could carry instruction directly into every community hospital. Such an undertaking is still some way off, for the regional hospitals must mature into strong teaching units before they can extend to outpost hospitals the kind of educational assistance they now receive from the Boston center.

On the whole, the Bingham organization has done an extremely effective job. Not the least remarkable feature of its program is that the expenditures by the Fund have never exceeded $50,000 a year for each regional group. Costs were held down by moving one step at a time and by transferring the Fund's activities to the participating hospitals as rapidly as possible. Its directors—Dr. Samuel H. Proger, medical director of the Pratt Hospital, and Dr. Crosby—regard the whole program as a demonstration, not a philanthropy. Their efforts have been directed toward proving that the regional hospital plan is economically feasible and medically sound.

Up to the present year, the Bingham

SPECIMEN OF TISSUE is prepared for mailing in the community hospital at Castine. Specimens, like X-ray plates, are sent from the community hospitals to the regional hospitals and, if necessary, to the New England Medical Center. Most of the work, however, is done in regional hospitals.

TECHNICIANS ARE TRAINED in the School of Medical Technology at Lewiston's Central Maine General Hospital. This training is one of the crucial activities of the Bingham plan. Technicians, although there are seldom enough of them, help alleviate the shortage of community doctors.

Associates' sole venture into building was the construction of the Pratt Hospital. This summer, however, the Pratt acquired a new surgical wing and laboratories which herald a new development in the Bingham program. During the next few years, the Fund plans to develop an extensive surgical program. One of the principal surgical projects is research to simplify a number of important but extremely complicated operations, so as to adapt them to the small community surgeon and operating room.

This surgical research project aptly highlights the objective of the Bingham program and, indeed, of the entire concept of regionalization. The purpose is not only to provide rural people with a higher quality of medical care, but to provide it close at hand. While future regional groups may plan to furnish some facilities for treatment of rural patients in city hospitals (a compromise suggested by the U. S. Public Health Service), the primary orientation of the regional hospital plan is toward helping the small-town doctor to take better care of his patients in the community where he and they live.

SOME medical authorities have argued that plans of this type for strengthening rural hospitals are unnecessary, on the ground that the automobile affords ready access to the city. This overlooks the fact that more than half of all farm families do not own cars, and that medical emergencies occur in which the patient cannot be moved any distance. The Bingham Associates further point out that treatment and hospitalization at a distant center are a heavy financial drain on the patient and disrupt the living pattern of his family.

The Bingham plan obviously is not an answer to all the problems of rural health. The health of the 70 million Americans who live in areas that are rural in a medical sense is affected by a quantitative as well as qualitative deficiency of doctors and hospitals, by inadequate water supply, sewage disposal and so on, by poor housing and, in some parts of the country, by poor diet. The elimination of these deficiencies is a separate and difficult undertaking. Nor does the regional hospital plan touch upon the problem of payment for medical care, or the question of whether the individual practicing physician should be replaced by the clinical group. Nonetheless, the system of hospital organization pioneered by the Bingham Associates appears to be the most effective method yet devised for making modern medical knowledge available to the rural U. S. Whatever other steps may be taken to improve rural medicine, something like the Bingham plan seems a basic need.

Leonard Engel is author of magazine articles on medicine and other subjects.

SPECIMENS ARE EXAMINED in the pathology laboratory at Central Maine General. The specimens, which have been sent in by community hospitals, are lined up in front of pathologist Dr. John Rock. When the analysis is complete, the diagnosis is sent to community hospital. The laboratories of the Bingham plan's regional hospitals are busy. Last year this one made 8,000 analyses of tissue sent in from community hospitals.

LONG-RANGE FORCES

Alexandre Rothen's proposal that they may account for specific chemical reactions between molecules that are not in contact has begun a heated debate

by Thaddeus Stern

OUR concept of the chemical behavior of all matter is founded on the assumption of intimate interactions among molecules. One molecule encountering another of a different kind enters into some sort of direct physical contact with it; it may unite with, reshape, split or completely disrupt the second molecule, and fundamentally this process is supposed to account for all chemical change, including life itself.

For some time, however, biologists have been puzzled by indications of a strange kind of molecular behavior that does not fit this accepted picture. Certain molecules, for instance those in the threadlike chromosomes of living cells, appear to affect one another at a distance in some mysterious way that cannot be explained by existing theory. And recently Dr. Alexandre Rothen of the Rockefeller Institute for Medical Research has aroused considerable interest among biologists and physicists by reporting experiments which, he concludes, actually demonstrate such long-range molecular interactions.

Dr. Rothen suggests that the most likely interpretation of his experiments is that there are specific long-range forces acting between molecules, and that chemical action between large molecules is possible even though they are very far from contact with one another! This is such a revolutionary idea that it has become the focus of much controversy.

Rothen's experiments deal with serum, antibodies, antigens and monomolecular films. A brief explanation of these terms will help make his experiments clear.

Blood consists of liquid plasma in which are suspended several different kinds of cells, including the oxygen-bearing red cells and various white cells. If the cells are removed from blood without clotting, plasma remains. If clotting is allowed to occur, however, a clear yellowish fluid is obtained. This is serum. Plasma and serum differ from each other principally in the fact that plasma lacks the clotting protein fibrinogen. Serum contains a number of inorganic salts and organic compounds, including various large protein molecules. Among these proteins, which form about seven per cent of the serum, are albumin and a number of globulins.

When an animal is injected with a foreign protein (antigen), it tends to produce a modified native protein (antibody), which has the remarkable property of combining specifically with the antigen. It is therefore called the homologous antibody for this particular antigen. The antibodies, protein molecules that play an important role in immunity to infectious disease, are found to belong with the so-called gamma fraction of the globulins.

Unlike organic molecules in the class of esters, sugars and so on, which contain a dozen to at most a hundred atoms, protein molecules have thousands of atoms. They are arranged around a coiled or folded chain structure, not unlike that of the synthetic molecules such as Nylon. Thus antibodies are conceived to have the shape of long, thin chains. The current view is that in the process of formation these chains can fold into a large number of different configurations.

If a molecule of antigen happens to be present during the synthesis of a protein in the living organism, it may shape the protein molecule by acting as an important organizing factor in the environment. Such a mechanism might well account for the highly specific nature of antigen-antibody reactions; the antigen and its homologous antibody fit each other like a mold and its cast. Specific and selective chemical action of this sort is a striking and characteristic property of biological substances. It is found not only in serum reactions but also in the interaction of enzymes and hormones with other substances, in the reproduction of genes, and so on.

At Rockefeller Institute Rothen has studied serological reactions between monomolecular films of antigens and their homologous antibodies. Films which are one molecule thick can easily be obtained with some substances on a clean water surface. An example of such a substance is stearic acid. Each stearic acid molecule contains a water-soluble (hydrophylic) section and a water-insoluble (hydrophobic) section. If a small drop of a dilute solution of stearic acid in benzene is placed on a water surface which has been skimmed clean, the benzene evaporates and the molecules of stearic acid align themselves with the hydrophylic ends in the water and the hydrophobic ends out of it. A monomolecular film is thus formed, and it can be compressed, expanded or transferred to a flat polished slide for further study.

Similar films can be prepared with proteins. Protein films, however, spread themselves in a somewhat different way. In their usual shape, protein molecules have thicknesses of the order of 25 to 100 angstroms (one angstrom = 1/100,000,000 centimeter), but on a water surface they form films which are only 6 to 10 angstroms thick, whatever their molecular size may be. This smaller thickness corresponds roughly to the average cross section of the protein's extended chain structure. Thus in the process of spreading on the water surface the coiled or ellipsoidal shape of the native protein molecule has been unfolded into a new and thinner configuration.

UNFOLDING impairs or even destroys the biological activity of proteins in some cases but not in others. Films of some pituitary hormones, for example, lose most of their hormone activity, while films of the hormone insulin remain fully active. Films of egg albumin and of serum albumin from human beings, horses and cattle all retain their full ability to react with their homologous antibodies.

Rothen's much-discussed experiments have been carried out mostly with films of albumin from cattle, which retain their serological activity very well. The homologous antibody for his work was obtained by injecting this bovine albumin into rabbits and using the resulting rabbit serum containing the antibody for bovine albumin.

In the experiments Rothen uses a rectangular trough filled to the brim with water. The water surface is first skimmed clean by sliding a polished, chromium-plated metal bar over the top of the trough. Films of the antigen (bovine albumin) are then spread on the surface. The films can be compressed by sliding other bars over the trough surface. They may then be transferred to a flat, polished, chromium-plated slide by dipping the slide vertically into the water. If the film is picked up on the downward movement of the slide, the hydrophobic side of the film faces the slide and the hydrophylic side remains exposed; if it is picked up on the upward motion, when the slide is drawn out of the water, the sides are re-

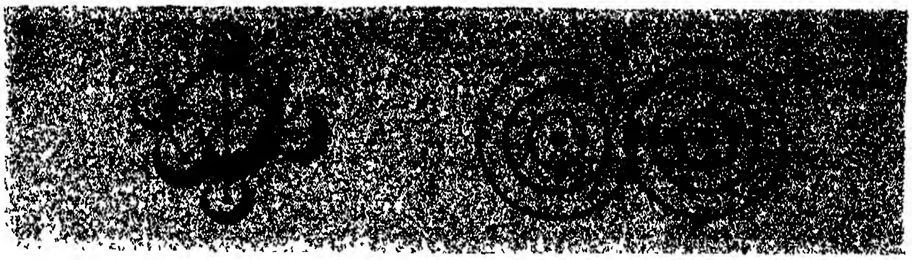
versed. A "round trip" dipping results in the transfer of a double film, presenting a hydrophobic or a hydrophylic outer surface, depending on whether the trip is started from above or below the water surface. Many alternating films can thus be picked up on one slide, and it is also possible to pick up a series of "down" films or of "up" films by spreading a new film for each dip.

After this process has been completed, the antigen-covered slides are brought into contact with a solution of serum containing the antibody. The slides are then rinsed (without washing off the films) and dried. Now comes the crucial part of the experiment: measurement of any change that may have occurred in the films' thickness. Since all of Rothen's deductions are based on these observations, his method for making accurate measurements should be described.

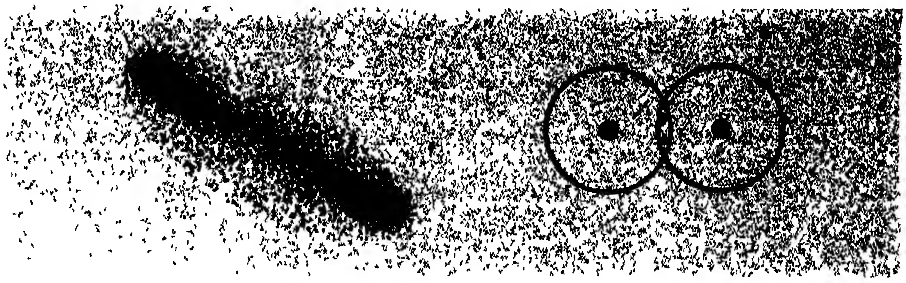
Because the existing techniques for determining the thickness of films were relatively crude, with an uncertainty of 15 to 30 per cent, Rothen designed a special instrument, the ellipsometer. The operation of this instrument is based on the fact that linearly polarized light is elliptically polarized when it is reflected from a metal surface. The shape and angle of the ellipse of polarization depend on the angle of incidence of the light and on the optical constants of the metal. A thin, transparent film alters the optical constants in proportion to the film's thickness. Rothen's ellipsometer measures the degree of this alteration.

To use the ellipsometer as a measuring instrument, a metal slide is first coated with an "optical gauge" as a standard or point of reference. For this purpose, the clean, polished slide is covered with one or more films of barium stearate, a compound that forms films of known thickness. Half of the slide then is covered with two additional layers of the same film. The difference in thickness of the films covering the two halves of the slide results in a difference of ellipticity of the light reflected from these two half fields. Consequently when they are viewed through the ellipsometer they appear of unequal intensity. By rotating a polarizing filter in the ellipsometer, the intensity of both half shadows can be equalized. The corresponding angle is then recorded as the zero reading for the slide before films of unknown thickness are measured. These need be deposited only on the central part of the gauge-covered slide. The added layers disturb the original optical balance, and the angle of rotation of the polarizing filter that is required to restore equal shadow intensity is a measure of the thickness of the added film, accurate to within one third of an angstrom.

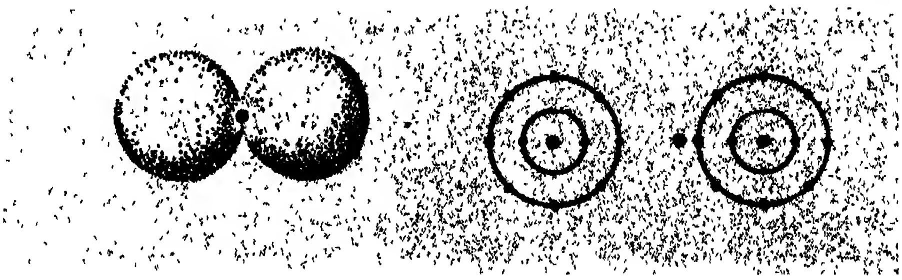
Rothen found that films of bovine albumin on his slides, after being treated with rabbit antiserum containing the homologous antibody, increased in thick-



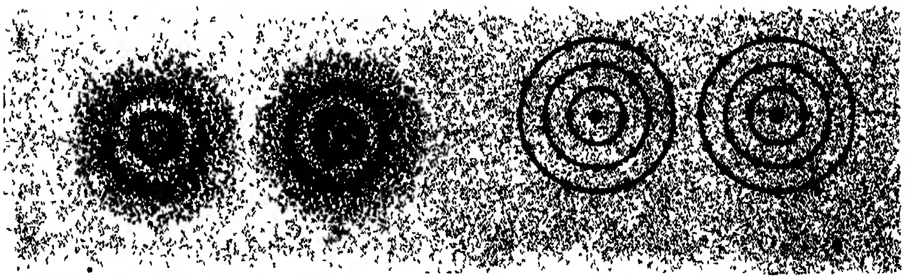
IONIC BOND is one of accepted relationships between atoms. Example: sodium chloride. At left is crystal arrangement of sodium and chlorine. At right is diagram of electron structure. Ions are held by electrostatic charge.



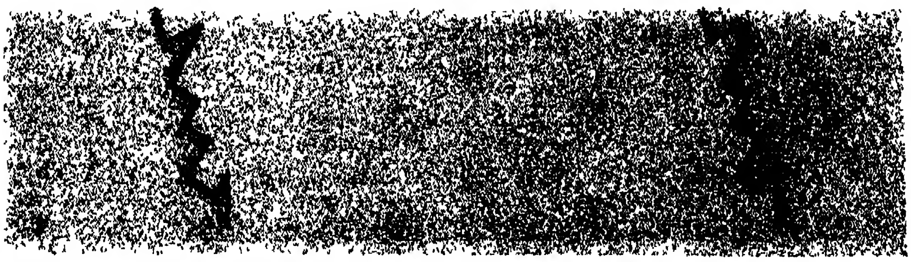
COVALENT BOND entails the sharing of two electrons by two atoms. The simplest example is the hydrogen molecule, H_2. At left is electron cloud model of molecule; at right is diagram of its two nuclei and two electrons.



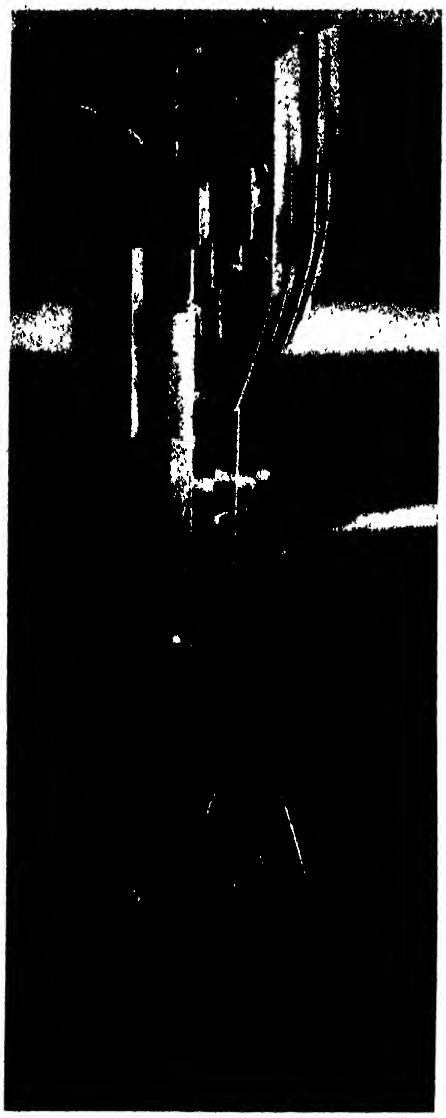
HYDROGEN BOND utilizes the stripped nucleus of hydrogen as a bridge between two negative ions. In this case the positive hydrogen nucleus (*dot between atoms in diagram at the right*) links two ions of fluorine.



VAN DER WAALS FORCE is a weak attraction between atoms. Example is the noble gas argon, which forms no chemical combinations. Nucleus of one atom has slight attraction for electrons of the other, and vice versa.



LONG-RANGE FORCE is believed by some to exist between two widely separated large molecules. Here two protein molecules are shown in highly schematic diagram. Interacting molecules have mold and cast configuration.



SLIDES are dipped in a tank of water to coat them with monomolecular film. Film floats on water surface.

"BLANKET" of plastic is rectangle floating on water. Slide bearing antigen film is pressed down upon it.

ness by an amount that was consistent with the estimated size of the antibody molecules. Treatment with normal, antibody-free serum resulted in very little or no increase in thickness. This observation merely shows, of course, that the antigen in the films retained its specific ability to combine with the antibodies; the antibodies which thus became bound to the antigen caused the thickening of the films.

Rothen also found, however—and this is the surprising fact—that if the antigen films were covered with films of barium stearate, of the plastic Formvar or of other materials that might have been expected to act as a screen, subsequent treatment with antiserum still resulted in an increase of thickness, even though the screens in some cases were several hundred angstroms thick. In other words, the antigen and antibody appeared to be able to interact even through a barrier between them! The influence of the barriers depended mainly on their thickness and very little, if at all, on their nature, except that any metal film thick enough to be continuous blocked the activity. Perhaps more surprising still is Rothen's additional observation that the increase in thickness was greater if more than one layer of antigen was deposited on the plate. It increased in direct proportion to the number of such layers. It also depended on the orientation of the films, *i.e.*, on whether the hydrophylic or hydrophobic side was uppermost.

It was to account for these unexpected results that Rothen made his assumption of specific long-range forces operating between molecules, at least in the case of oriented films. The distances involved here are on a microscopic scale, of course, but the phenomena observed are so surprising, in view of the current theory about how molecules should behave, that the distances might as well be astronomical.

LET us consider the historical context of this proposition. The phenomenon of action at a distance perplexed the earliest philosophers. Speculation about the behavior of celestial bodies led the Greek philosophers Democritus and Epicurus to vague hypotheses of the tendency of the earth and the stars to a common center. Later, Johann Kepler, Galileo and others assumed the existence of a mutual attraction between the sun, the earth and other planets. This assumption Isaac Newton formalized in the law of universal gravitation, stating that every body attracts every other body by a force which is proportional to the product of their masses and inversely proportional to the square of the distance between them. When investigators discovered that action at a distance also manifested itself between electric charges, Charles Augustin de Coulomb was able to formulate his well-known electrostatic law, which is in form quite analogous to Newton's law of gravitation but which accounts for repulsions as well as attractions at a distance, depending on whether the electric charges are of similar or of opposite sign.

These gravitational and electrostatic forces, and the later discovery of magnetic forces, provide a satisfactory explanation of physical action at a distance. But they fail completely to provide any theoretical hint to account for the remarkable specificity of the biochemical reactions of the type described by Rothen.

There is a type of intermolecular attraction produced by short-range forces known as the van der Waals forces, named for the Dutch physicist Johannes van der Waals, who discovered them. These are believed to result from the mutual interaction between the electrons of one atom and the nucleus of another. This attraction seems to be slightly greater in strength than the force of repulsion of electrons by electrons and nuclei by nuclei; hence it accounts for short-range attractions between molecules.

Another well-known type of molecular or interatomic force is the so-called hydrogen bond. This bond is formed by a bare hydrogen nucleus stripped of its single electron. The positively-charged nucleus tends to attract electrons and thus acts as a bridge between an atom in one molecule and an atom in another. It is weaker than an ionic bond, in which two atoms of opposite electric charge are attracted to each other; or a covalent bond, in which two electrons are shared by two atoms; but it is stronger than a van der Waals force.

It is possible for at least some of these well-known forces to transmit their influence to considerable distances through effects in intermediate atoms and molecules, but physicists have not been able to formulate any such mechanism that could account for the specificity required to explain Rothen's results.

This dilemma has resulted in considerable controversy among scientists. Let us therefore scrutinize Rothen's assumptions. He assumes that his films remain essentially flat and that antigen or enzyme molecules do not get through the screening barriers. But his measurements of the thickness of the films are no proof at all of the validity of these assumptions. His measurements give only the average thickness of the films; they leave open the question of whether there are places where the antigen films are not completely covered and molecules can get through.

Linus Pauling of the California Institute of Technology has suggested, and many physicists and chemists agree, that it is highly probable that Rothen's assumptions are not valid and that actual atomic contact takes place between the interacting molecules. On the other hand, Rothen's experiments have been repeated and confirmed at the research laboratories of the General Electric Company. Irving

Langmuir of General Electric, the English physicist J. D. Bernal and others believe that the experiments actually do demonstrate chemical reactions at a distance.

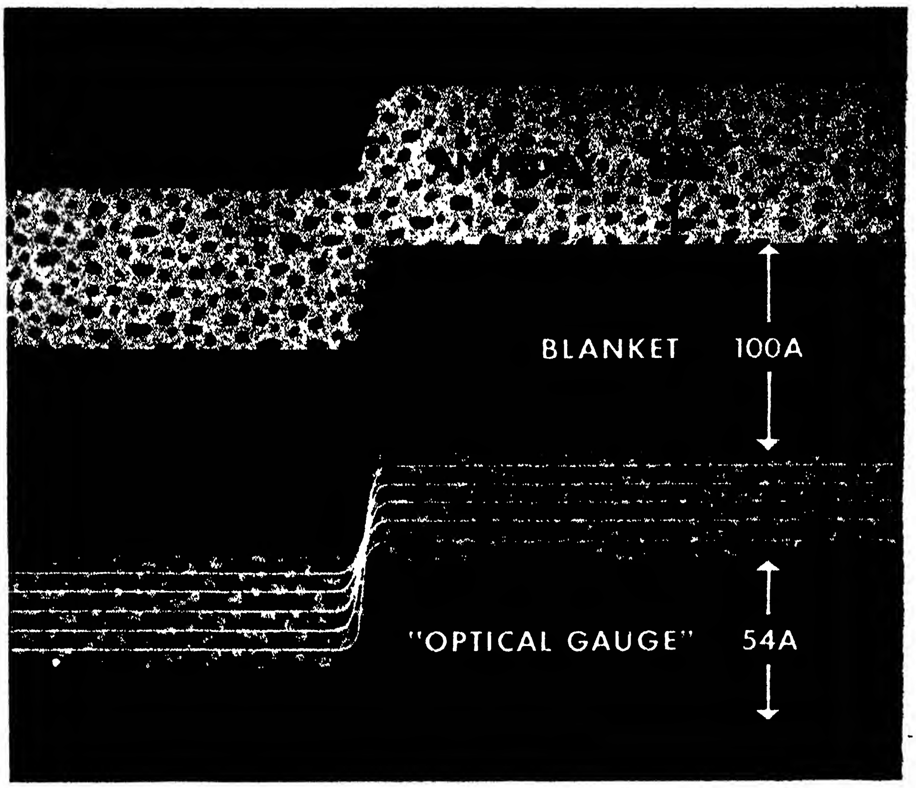
Recently the question was discussed by a number of eminent scientists at a symposium of the Polytechnic Institute of Brooklyn under the chairmanship of Peter J. W. Debye. The discussion considered two possibilities: 1) that there might be holes in the barriers; 2) that the underlying antigen film might buckle or clump in such a way as to create sharp peaks and valleys; the screening materials might well fill the valleys but leave the peaks exposed.

Rothen pointed out that if the "hole" theory were correct, it would take some time for the molecules to diffuse from one layer to another, and that different screens would be expected to give different sizes and concentrations of holes and therefore different times. He found no such effects. As for the "peak and valley" theory, he thought it improbable, since a single film of barrier material fully protected a film of insulin from the action of the relatively small protamine molecule, with which insulin readily reacts. It is possible, however, that insulin films may not buckle while bovine albumin films may. In fact, electron microphotographs were shown which clearly indicated the presence of peaks in bovine albumin films. Similar photographs made by Rothen, however, showed the peaks to be insufficiently high, in his opinion, to sustain this objection. He also reported that separately prepared barriers of Formvar, which were shown to be free of holes, gave the same results as liquid deposits of Formvar films.

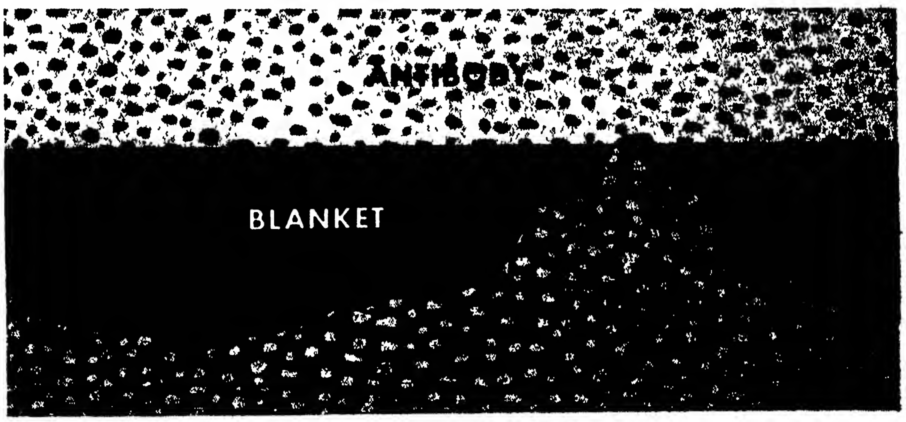
Evidence for what appear to be long-range forces between the large rod-shaped molecules of tobacco mosaic virus has been presented by Dr. I. Fankuchen of the Polytechnic Institute of Brooklyn. In X-ray studies made together with J. D. Bernal in England, he found that the virus molecules remained parallel to one another, with an endwise hexagonal arrangement, in swelling gels of the substance. L. Onsager of Yale University has presented a theory to account for this phenomenon, however, on the basis of the elongated shapes of the molecules and of short-range forces, without invoking new long-range forces. But no application of this theory appeared to be able to account for Rothen's film experiments.

And so the dilemma stands. Further work will show whether Rothen's assumptions are valid or not. If they are, his revolutionary concept of specific chemical action at a distance will require many readjustments in the thinking of physical chemists.

Thaddeus Stern is the pen name of a well-known investigator in the field of physical chemistry.

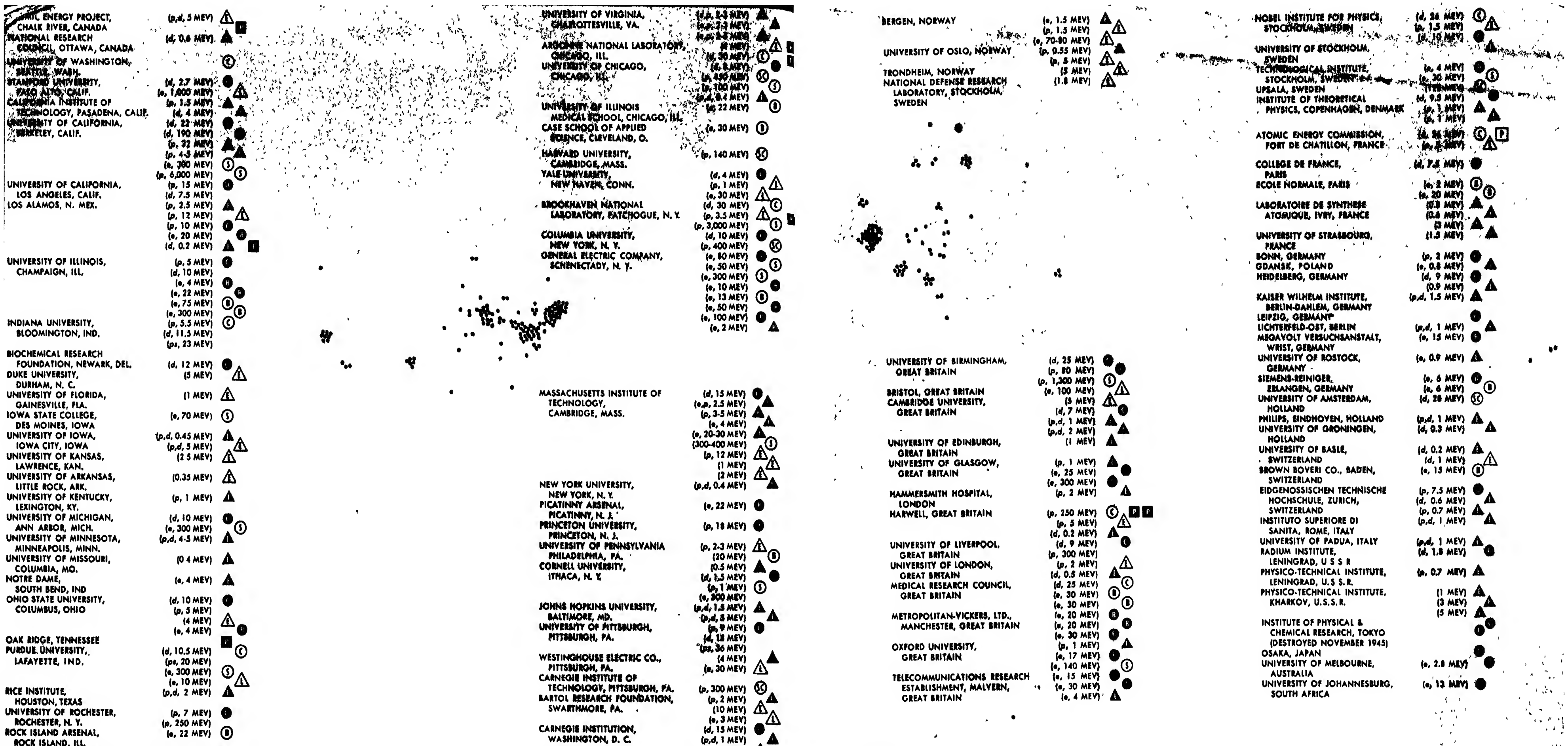


CROSS-SECTION drawing of Rothen experiment shows relationship of films. Optical gauge (standard for thickness measurement), antigen and blanket are deposited. If antigen sticks to blanket, interaction has occurred.



POSSIBLE FLAW in the Rothen experiment is that the layer of antigen is not smooth, but has peaks and valleys. A few of the peaks might then remain exposed above the blanket and thus would react with the layer of antibody.

ANOTHER FLAW proposed in the experiment to explain Rothen's observations is that the blanket might be punctured with holes, permitting the layers of antigen and of antibody to come into contact with each other.



KEY

BOMBARDING PARTICLE

- e ELECTRON
- p PROTON
- d DEUTERON
- ps HEAVIER PARTICLES

ENERGY OF BOMBARDING PARTICLES

MEV MILLIONS OF ELECTRON VOLTS

TYPE OF MACHINE (● COMPLETED ○ PLANNED OR BUILDING)

- Ⓒ CYCLOTRON
- Ⓢⓒ SYNCHRO-CYCLOTRON
- Ⓑ BETATRON
- Ⓢ SYNCHROTRON
- ELECTROSTATIC GENERATOR
- LINEAR ACCELERATOR
- RESONATOR
- Ⓟ ATOMIC PILE

WORLD'S ACCELERATORS

The machines used to penetrate the nucleus of the atom are scattered over the earth. Herewith a map showing those known to U.S. physicists

Where men study the structure of the atom, they build great machines to fire high-energy particles into its nucleus. These are the machines that go by such 20th-century names as cyclotron, synchrotron and betatron. Scattered over the world, they are among the characteristic artifacts of modern civilization.

The map above is based on a list of the world's accelerators recently compiled by H. H. Goldsmith of Brookhaven National Laboratory. The map shows all accelerators known by U. S. physicists to be completed or building or immediately planned for nuclear research. It includes only a few of the machines used primarily to generate X-rays. It also shows the eight atomic piles that have been built for research purposes, although these are technically not accelerators.

The type on the map is arranged approximately according to the location of the accelerators. In the U.S.S.R. the map shows only the machines that are known to have been in existence before the war. It also shows German accelerators not presently in service.

GROUND SECTION OF TOOTH shows a lamella, a thread of comparatively soft organic material, running vertically from the surface of the tooth (*top*) through the enamel to the dentin. It is these lamellae, states the author, that are the avenue for the invasion of the teeth by bacteria.

A NEW

FOR CENTURIES it was believed that holes in the teeth were excavated by worms. Even today, in remote parts of China, professional extractors of worms from the teeth offer their skill in the market place. The practitioner conceals in the palm of his left hand some dried worms of a variety found in the roots of willow trees. He explores the mouth of a suffering patient with a pair of chopsticks. Bystanders peer curiously into the open mouth. The practitioner, with a deft twist of the chopsticks, surreptitiously plants one or two of the tiny dried worms in the cavity of the sufferer's tooth. In the saliva the worms soon swell. The "dentist" then triumphantly removes them and collects his fee.

Modern dentistry has advanced somewhat beyond that point, but we still have tooth decay and toothaches on a huge scale. The cause of tooth decay has remained a baffling mystery until recently. Why do people who seem otherwise perfectly healthy lose their teeth? Why are children more subject to dental caries than grownups?

Of the theories offered in modern times one of the most firmly implanted is that sugar is bad for the teeth. It is true that a tooth which is sensitive to sweets usually develops a carious cavity. But why do some children have a "sweet tooth" and others not? Again, there are few slogans that civilized man accepts more thoroughly than the one that "a clean tooth never decays." But no one has explained why children of the same family, who clean their teeth in exactly the same way, vary a great deal in the cleanliness of their teeth and in their susceptibility to caries.

The fact is that none of the theories suggested in the past has enabled us to solve our fundamental problem, namely, the prevention of tooth decay. This article will present a new view on the cause of dental caries based upon extensive research. These studies have yielded a demonstrably successful method of preventing caries.

The teeth are a unique kind of biological structure. All the rest of the human body is covered with a more or less horny layer of epithelial tissue, or skin, which blocks bacteria and is constantly sloughed off and renewed, thus preventing invasion of the deeper tissues. The teeth alone have no epithelium, for it would soon be destroyed by chewing. Instead, they have a hard shell of enamel, covering the softer dentin that makes up the body of the tooth. The enamel is exceptionally vulnerable to bacterial invasion. Why? That is the basic question that has stumped dental researchers for hundreds of years.

As early as the 16th century, a German

THEORY OF TOOTH DECAY

The originator of a simple new treatment which seems to offer hope of preventing the common affliction states his argument

by Bernhard Gottlieb

investigator proposed the theory that the teeth were destroyed by acids dissolving the enamel. Later the Englishman Watt, observing that some tooth cavities were brown, others yellow and still others white, suggested that the various colors were due to attack by different acids—nitric, hydrochloric and sulfuric. Shortly afterward another Englishman dryly remarked that he had made inquiries and found that nobody was drinking the acids in question. Other investigators suggested that dental caries was caused by inflammation of the tooth structure. But it was shown that there were no blood vessels in the hard tooth structures and hence there could be no inflammation.

Eventually the acid theory was revived, and it remains the prevailing view today. It seemed "common sense" that hard, calcified structures such as the teeth could be attacked only by acid. For a long time the fermentation of carbohydrates, especially of sugar, was considered the source of the acid that caused dental caries. When Louis Pasteur showed that microorganisms produce lactic acid (thus converting sweet milk into buttermilk), it seemed that the answer had been found. To prevent dental caries, it was proposed to starve these acid-producing microorganisms by eliminating carbohydrates, especially sugar, from the diet. But when it was demonstrated that many children were immune to dental caries, no matter how much sugar they were fed, it became clear that there must be something basically wrong with this theory.

Yet dental caries does seem to be associated with an increase in a certain kind of microorganism. In 80 per cent of the examined cases, caries-susceptible children have been found to have exceptional numbers of these organisms in their mouths. Researchers have therefore assumed that the bacteria are the primary cause of caries. In doing so, they appear to have made an error common in medical research—mistaking an effect for a cause.

Consider a disease that is in many ways similar to caries—trench mouth. This disease, which came into prominence during the First World War because of its high incidence among fatigued soldiers in the trenches, is an inflammation of the soft tissues of the mouth. Because bacteriological tests showed that certain microorganisms normally found in the mouth were present in greatly increased numbers in trench-mouth patients, the disease was considered primarily an infection. Recently, however, it has been found that injection into experimental animals of a chemical that seriously depletes vital resistance can produce the same disease. A New York dentist also has observed that high-school students often develop trench mouth at the time of a difficult examination, after a period of little sleep, much smoking and consumption of large amounts of black coffee.

Obviously, then, the primary cause of trench mouth is not the presence of the germs but the lowered resistance of the mouth tissues, due to weakened health. The ever-present organisms take advantage of this and increase in number. The tissues concerned have acquired a quality favorable to the organisms' growth, and that change in quality must be considered the primary pathological change.

DOES some such process occur in the teeth? If the tooth enamel were entirely calcified, this would be unlikely, for it would then be true that only some chemical action or mechanical injury could open the solid enamel to bacterial invasion. But in 1878 a New York dentist named Bodecker discovered an important fact, the significance of which, unfortunately, was not realized at the time. He found that there were threads of an organic, noncalcified material running through the enamel. These were incorrectly interpreted as vessels for the circulation of nutrients to the enamel. Attempts were made to connect this finding with an explanation of dental caries, but they were unsuccessful.

This long neglected observation has now turned out to be the vital clue to the problem. Our recent studies of these organic threads leave no doubt that they are the invasion roads for destruction of the teeth. The threads, it is found, constitute about five per cent of the enamel structure, the remaining 95 per cent being calcified. The threads vary in thickness; the thicker ones, called *lamellae*, extend through the enamel from its outer surface to the inner dentin, which is only 33 per cent calcified. It is through the lamellae that microorganisms attack the vulnerable inner tooth. Under certain conditions, probably having to do with the quality of the saliva, the lamellae resist invasion. But when they offer conditions favorable to bacteria, the germs multiply, and decay of the dentin proceeds rapidly.

This concept explains at once many of the puzzling facts about tooth decay. If the action of acid were responsible for producing cavities, we should expect to find the greatest damage at the surface of the enamel, for under the right conditions enamel melts away on exposure to acid like snow under a bright sun. Actually, as every dentist knows, the damage from caries is much greater in the dentin beneath the enamel than in the enamel itself. The microorganisms, entering through the narrow lamellae, by-pass the more resistant enamel and attack the less calcified inner structure. Often there may be wide destruction in the dentin while the enamel remains intact; the dentist has to chisel away the covering enamel to prepare the cavity for filling. Sometimes a tooth that seems to be intact apparently develops a hole overnight. The hole has actually been present in the dentin for some time, and is exposed by a sudden collapse of the undermined enamel.

Thus we see that tooth decay is produced by a process exactly opposite to attack by acid. The calcified parts of the tooth, which are vulnerable to acid, are the most resistant to caries; the organic parts, which resist acid, are most vulnerable to caries.

We are now in a position to clear up several seeming paradoxes. It has long been known, for example, that carious enamel is more resistant to acid than is intact enamel. If acid were the cause of caries, this situation would be inexplicable. But carious enamel is actually enamel that has been infiltrated by microorganisms. Microorganisms are protein bodies that resist acid action. Hence, carious enamel is more resistant to acid because it contains a larger proportion of organic material.

Conversely, enamel that has been attacked by acid is more resistant to the spread of caries. The caries process is usually accompanied by acid production. When the acid dissolves a part of the calcium salts of the enamel, the solution of calcium salts diffuses out to the periphery. Since conditions there are less acid, the salts are precipitated, forming a hypercalcified strip. This hypercalcified strip represents a barrier against microorganisms and thus stops the spread of caries.

This explains why some adults may have stable cavities in their teeth for decades, without the decay ever reaching the pulp (nerve). The hypercalcified strip has created a permanent barrier against decay. Indeed, without this "acid defense" the ravages of dental caries in the human race would be catastrophic.

The accompanying photomicrographs of sections of teeth supply the proof of these assertions. They show the lamellae and smaller organic threads running through the enamel, the spread of caries in the dentin while the enamel remains intact, and the sealing of a cavity by hypercalcification in its periphery.

We now have a clear picture of our problem: how to close the lamellae against invasion by the caries-producing microorganisms. We know that the teeth have some natural defenses. If nature had no method of guarding against such invasion, every tooth would become carious, for the enamel of all animals, including human beings, normally have lamellae, and microorganisms producing caries are present in every mouth. Many individuals possess a lifelong immunity to dental caries, while others are susceptible at some periods and become immune at others. Most people seem to gain immunity at about the age of 20. Unfortunately, the period of greatest susceptibility is during childhood, and teeth lost then obviously cannot benefit from a later period of immunity.

ALTHOUGH there is good reason to believe that the character of the saliva determines the degree of immunity of the teeth, we do not know what the protective quality is. It may be that the saliva deposits calcium salts in the lamellae, thus blocking the invasion roads. Perhaps we may eventually learn enough about metabolism to control the quality of saliva by diet and thus prevent tooth decay. But that appears to be far in the future. In the meantime, we can take a short cut and block the invasion roads by artificial means.

This protection can be provided by precipitating insoluble salts in the lamellae. The chemical compound now being used for this purpose is 40 per cent zinc chloride precipitated with 20 per cent potassium ferrocyanide. The compound produces a white salt, so the teeth are not discolored. It penetrates the entire length of the lamellae to the dentin. A series of such treatments during childhood permanently seals the enamel against bacterial invasion. The treatments have proved capable of reducing dental caries by about 90 per cent.

There is an easy test for the effectiveness of this impregnation. When a tooth is sensitive to cold, it means that the invasion roads in the dentin are open; sensitivity of the dentin and susceptibility to dental caries are based on the same biological principle. Hence if the chemical impregnation desensitizes sensitive dentin, that is clear proof that it has closed the invasion roads to bacteria. The same principle applies to a sweet tooth. When the lamellae are blocked, the tooth's sensitivity to sugar disappears.

Our findings also explain why some teeth are hard to keep clean. When the lamellae are unobstructed, food particles stick to the surface of the enamel at their entrances. The accompanying illustration shows how foreign matter collects at these points. But when the lamellae are blocked with insoluble salts, debris cannot get a foothold at the entrances, and the teeth become astonishingly easy to clean; the flow of saliva alone is sufficient to keep them gleaming. So the slogan, "A clean tooth never decays" might more correctly be worded, "A caries-immune tooth is easier to clean."

It has long been suspected that the teeth are a route of entrance for the virus of infantile paralysis. A few years ago M. S. Aisenberg and T. C. Grubb of the University of Maryland Dental College reported that they could produce poliomyelitis in monkeys by inoculating the pulps of their teeth with the virus. Then they examined 375 poliomyelitis patients and found that 65 to 70 per cent of them had exposed pulp in their teeth; of a comparable group in the same area who did not come down with poliomyelitis, only 24 to 27 per cent had exposed pulp. Impregnation of the teeth would close these avenues to the virus. It appears that we could do a magnificent job in our fight against infantile paralysis by at least impregnating the teeth of all school children.

Impregnation treatments for the prevention of caries should begin with the baby teeth. Such treatments have proved especially advantageous when the teeth have so many cavities that fillings are out of the question. Impregnation of such teeth hardens the walls of the cavities and prevents exposure of the pulp.

TOOTH DECAYS when infection is carried by lamellae through enamel to dentin. Here lamella is dark vertical marking. Infection in dentin is dark area spreading along the boundary between the enamel and the dentin.

The most important step toward preventive saving of the permanent teeth is to take care of the first molars as soon as they have started to erupt. Here we may use 10 per cent silver nitrate with adrenalin hydrochloride, which is preferable to the zinc chloride preparation because the teeth do not need to be kept dry as long. Although silver nitrate darkens the teeth, it is not noticeable on the molars.

After the eruption of the first molar, new teeth and new belts of teeth erupt continuously until the age of 12. They must be impregnated at least twice a year in order not to leave new portions of the teeth unprotected for too long. When the permanent teeth are fully erupted, proper impregnation apparently will protect them for a lifetime.

If a tooth is chipped or broken, however, it should be impregnated at once, for such a fracture exposes thousands of tubuli in the dentin which are entrances

for infection. The treatment will save the tooth; it should be continued until the tooth is completely insensitive to cold.

Impregnation also has proved of great value in preparing teeth for fillings or crowns. It not only protects against infection but avoids leaving the filled teeth sensitive to cold—a common aftermath of dental work which has made the life of many a patient and his dentist miserable. In our practice we always impregnate every freshly cut tooth surface until it cannot feel cold water or cold air. One of the possibly minor benefits of the impregnation treatment is that children can eat all the sweets they want without harmful effect, at least so far as their teeth are concerned.

Many recent studies indicate that fluorine, either in drinking water or in the form of a solution applied to the teeth, may increase the resistance of the teeth to caries. The explanation most commonly suggested is that fluorine either inhibits the formation of acid in the mouth or makes the enamel and dentin of the teeth more resistant to acid. Obviously, if our theory that acid is not the cause of caries is correct, this is not the true explanation. The following theory seems to me more likely: Fluorine is known to have a marked affinity for calcium. Fluorine deposited in the lamellae, therefore, would attract calcium from the surrounding enamel, forming an insoluble salt that would block the lamellae. This is a much less effective process, however, than impregnating the teeth; in a two-year experiment in which sodium fluoride was applied to the surface of the teeth, the reduction of dental caries was about 34 per cent, as compared with 90 per cent effectiveness achieved by the impregnation method. The relatively small effect of the fluoride application is emphasized by the fact that the two per cent solution applied does not desensitize dentin.

Fluorine in drinking water seems to produce its effects principally by contact with the teeth, for it has been found that the reduction of caries is several times greater in the front teeth than in the posterior ones. For several reasons (relative lack of protection for the rear teeth, individual variations in water drinking, the fact that only a part of the population is supplied with communal water) the treatment of water with fluorine cannot be regarded as a solution for the problem of dental caries. Combined with the positive impregnation treatment, however, it may be of great assistance.

In any case, it seems safe to say that a new era in dentistry is beginning, an era in which the prevention of tooth decay has become a practical possibility.

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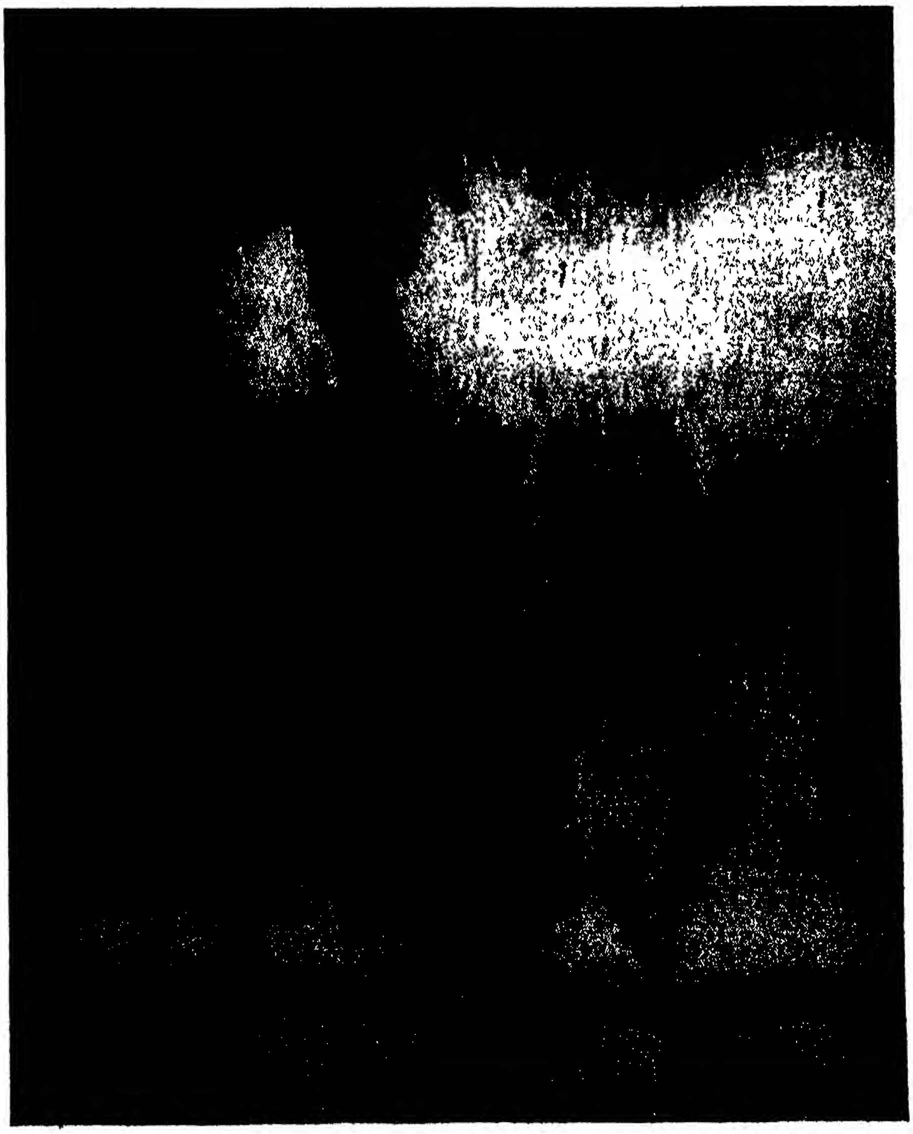
X-RAY SECTION of a tooth shows an advanced process of decay. Although the enamel is almost intact, the dark area beneath it indicates that the dentin has been decalcified and softened by acid accompanying invasion of bacteria.



PLUGGING of the lamellae is illustrated by a section of tooth that has been stained with silver nitrate. Chemical has penetrated to the dentin, leaving a dark spot. Other plugging chemicals are used to prevent decay.

SCIENCE AND

Scientists and the Government

DURING the past year, the Federal government has found scientists and technical personnel increasingly unwilling to accept or continue in government jobs. A recent survey by the United Press, for example, reports that 55 top-level Federal jobs are currently vacant. Thirty-three of them are scientific posts. President Truman, Chairman David Lilienthal of the Atomic Energy Commission and eight of the nation's leading scientists have stated that this situation is due (in the words of the President) to "attacks on scientists in the ostensible name of security."

On Labor Day the eight scientists addressed telegrams to President Truman and Thomas E. Dewey, charging that "irresponsible smears" of scientists had reduced the number of highly capable men in atomic energy laboratories to near the danger point. All but 15 of the 150 outstanding scientists engaged in wartime atomic research have quit the government since the end of the war, a substantial number out of reluctance to work where they are subject "to the possibility of irresponsible smears that may ruin them professionally for life." The attacks were termed "an imminent threat to our national security and entire governmental atomic research program." The telegrams were signed by Harrison Brown, Thorfin R. Hogness and Harold C. Urey of the University of Chicago; President Karl T. Compton and Philip M. Morse of the Massachusetts Institute of Technology; Dean George B. Pegram of the Columbia University Graduate Faculties; Charles C. Lauritsen of the California Institute of Technology; and John C. Warner of the Carnegie Institute of Technology.

A week later, opening the centennial meeting of the American Association for the Advancement of Science, President Truman denounced "the creation of an atmosphere in which no man feels safe against the public airing of unfounded rumors, gossip and vilification" as "the most un-American thing we have to contend with today." Such an atmosphere, he said, "is the climate of a totalitarian country," and, by driving men from Federal employment, is a threat to the continuance of indispensable research.

At the luncheon of the AAAS-George Westinghouse Science Writing Awards three days later, AEC Chairman Lilienthal warned that "the sources of talent are being closed to government." Said Lilienthal: "For a long time there has been a reluctance to enter government service. . . . That service has now taken on an extra, an added unattractiveness: the risk of undeserved injury to a man's good name, his professional standing and his peace of mind through anonymous vilification, through attacks from what may be petty or prejudiced or malevolent sources." As a result, he said, the Commission has been unable to obtain scientific, engineering and management manpower needed at once to keep the AEC program moving forward.

In an interview with a New York newspaper, Professor Morse of M.I.T., one of the eight signers of the telegram mentioned earlier, said that the attacks on government-employed scientists were a factor in his resignation last June as director of the Brookhaven National Laboratory. A statement by the Association of Oak Ridge Scientists and Engineers emphasized that such attacks have also been partly responsible for a number of recent resignations from the Oak Ridge laboratory. The Federation of American Scientists' Committee on Secrecy and Clearance asserted that 76 scientists and engineers have been discharged or suspended from government jobs or positions with government contractors on loyalty charges. The FAS found that the majority had been denied hearings or a bill of particulars.

Federal recruitment of scientific manpower is currently under intensive study by the Commission on the Organization of the Executive Branch of the Government which was set up last year by Congress. The Commission, headed by Herbert Hoover, is nearly finished with the most elaborate analysis of the functioning of the government ever undertaken. The Commission is expected to recommend an extensive reorganization of several research agencies and an improvement in salary and status for senior government scientists. The Commission's authority does not, however, include the problem described by the President, AEC Chairman Lilienthal and the eight scientists.

Health Program

A COMPREHENSIVE ten-year program for improvement of the nation's health has been proposed by the Federal Security Administration. The program, which is described in a 186-page report by Federal Security Administrator Oscar R. Ewing, recommends a system of compulsory national health insurance. Measures are also proposed for the attainment of the following health goals by 1960:

1. A 40 to 50 per cent increase in the annual education of doctors, dentists and other medical personnel.
2. The addition of 600,000 hospital beds to the present national total of 900,000, and the organization of rural hospitals into regional groups around metropolitan teaching centers (*see* "The Bingham Plan," *page* 7).
3. Doubling of public health personnel and the establishment of public health units in all rural areas now without them.
4. Formation of a network of citizen groups in every state and community to aid in the continuous improvement of health facilities and standards.
5. A Federal nonmilitary medical research program totaling $80 to $100 million a year, focused particularly on chronic diseases.
6. Increased facilities for mental health.
7. Rehabilitation services for 250,000 disabled persons.
8. Facilities for assuring "the utmost degree of health" to every child.

The program would be a common enterprise of Federal, state and local governments. The cost, exclusive of health insurance, which would be financed by special payroll taxes and for which no figures are given, would be $1,107 million a year more than twice the current government outlay for health services. Three quarters of the increase would be borne by the Federal government.

Congo Research Center

A $9 MILLION research institute is being established in the Belgian Congo with funds supplied by the Belgian Government. It will be open to scientists of all countries and will provide facilities for physical, biological and anthropological studies of the African tropics.

The Institute, which has been named Institut pour la Recherche Scientifique en Afrique Centrale (IRSAC), will operate at least six research stations. The main station is to be on the high plateau between Lakes Kivu and Tanganyika. Others whose sites have been chosen will be in the equatorial forest region near the mouth of the Congo and in Katanga, the uranium mining province. There will also be stations for seismological studies, for research in the ionosphere, and for a high-altitude astronomical observatory. The first stations will be opened this year.

IRSAC is directed by Louis van den Berghe, professor at the Antwerp Institute of Tropical Medicine and visiting professor of tropical medicine at Tulane University. The Board of Administrators

includes three foreign scientists: Harlow Shapley, director of the Harvard College Observatory; E. B. Worthington, British biologist, and A. Chevalier, French botanist. The Institute, which will have a $500,000 annual Belgian Government subsidy as well as the $9 million endowment, will offer fellowships to foreign scholars.

IRSAC has as an ultimate objective the opening up of one of the richest and least-known sections of the globe. Because of the barrier to settlement and exploitation represented by the tropical forest, development of the Belgian Congo has largely been limited to the Katanga radioactive ore area and the Lake Kivu-Lake Tanganyika plateau. Research on the medical and ecological problems of life in tropical forest regions will constitute a large part of the IRSAC program.

IRSAC is the second institute to be founded since the war for all-round scientific study of the tropics. The other is the International Institute of the Hylean Amazon (SCIENTIFIC AMERICAN, May). The Hylean Institute is moving ahead. Its charter, drawn up at a conference at Iquitos, Peru, last spring, is now in process of being ratified. Meanwhile an interim commission is conducting field surveys, establishing a headquarters in the Brazilian Amazon city of Manaos, and drawing plans for six research subcenters to be located in five Amazon countries.

Social Science Institute

SOCIAL scientists called together this summer by UNESCO to discuss "Tensions Affecting International Understanding" are considering a unique project: an International Social Science Institute to train social science teachers in international cooperation and understanding.

The Institute would bring together social scientists of various countries for a year of common study at an early stage in their teaching careers. The Institute would begin with about 100 fellows annually, 10 or 12 in each of the major branches of social science. Selection of the fellows would be made by participating universities from among junior faculty members 25 to 35 years of age who could be expected to advance shortly to professional grade. The course of study at the Institute, which would be open to all countries whether or not they were members of UNESCO, would consist mainly of seminars within each social science and in related social sciences.

The Institute will probably change form several times before it finally materializes. The central idea was endorsed, however, by the senior conference delegates, including Gordon W. Allport, Harvard psychologist; Max Horkheimer, director of the Institute for Social Research, New York; and Harry Stack Sullivan of the Washington School of Psychiatry. Some conferees suggested that the Institute might be the first step toward establishment of an international university.

Chemical Center

EVERY year chemists prepare thousands of new compounds, most of which prove unsuited to the immediate purposes for which they were made and accordingly are shelved and forgotten. There is always the possibility, however, that some of them might be extremely useful for other unexpected purposes. Thus DDT and sulfanilamide were both prepared and discarded decades before their extraordinary biological powers were accidentally discovered. To minimize this kind of oversight, the National Research Council has organized a Chemical-Biological Coordination Center in Washington. With the aid of funds from the Army, Navy, National Cancer Institute and American Cancer Society, the Center is preparing a catalogue of the physical and chemical properties of old and new chemical compounds

Atomic Bibliography

A COMPREHENSIVE international bibliography of atomic energy is being published by the United Nations Atomic Energy Commission. The first of its kind, it will cover all phases of the subject, from the underlying theoretical physics to social effects.

The first volume, already issued, offers a selected list of 650 titles on political, economic and social aspects of atomic energy. The second, to be published early next year, will deal with scientific aspects. Prepared under the direction of H. H. Goldsmith, head of the information and publications section of Brookhaven National Laboratory, it will contain about 10,000 titles drawn from the scientific literature of the world during the past decade. Preliminary drafts of two sections of this volume, "Biological and Medical Effects of High Energy Radiation" and "Isotopes in Biology and Medicine," were issued last month. Other sections will cover "Fundamental Nuclear Science and Technology," "Physics and Engineering of Nuclear Reactors," and "Applications of Tracers to Non-Biological Sciences."

In the introduction to the scientific volume, J. Robert Oppenheimer of the Institute for Advanced Study, wartime director of the Los Alamos laboratory, points out that the bibliography is a measure of the restoration of free publication in science. Free publication is once more the rule in all fields covered by the bibliography, except the physics and engineering of nuclear reactors.

Arthritis Foundation

THE problem of arthritic diseases, which afflict an estimated 7,500,000 Americans, is to be attacked by a new agency, the Arthritis and Rheumatism Foundation. Set up by the American Rheumatism Association and other voluntary health agencies in this field, the Foundation will operate along the lines of groups like the American Cancer Society and National Foundation for Infantile Paralysis. The Foundation's board is headed by Floyd B. Odlum of the Atlas Corporation. It will support a research program, to be developed jointly with the National Research Council, and a graduate training program for practicing physicians.

Westinghouse Awards

THE top honors in the field of science journalism are the AAAS-George Westinghouse Science Writing Awards of $1,000 each, presented annually by a committee of the American Association for the Advancement of Science for the best newspaper science coverage and the best magazine article on science. This year's awards went to Frank Carey of the Associated Press and Florence Moog, assistant professor of zoology in Washington University at St. Louis. An honorable mention was awarded to Herbert Yahraes of Stanfordville, N. Y.

Carey received his award for a series of Associated Press dispatches on the promising antibiotic chloromycetin and its use against rickettsial diseases. Dr. Moog was honored for the article, "The Biology of Old Age," which appeared in the June issue of SCIENTIFIC AMERICAN. Yahraes won honorable mention for "Static from the Stars," an article on radio frequency radiation of stellar origin, in *Popular Science*. The Associated Press, SCIENTIFIC AMERICAN and *Popular Science* also received citations for distinguished service to science journalism.

Meetings in November

Geological Society of America. New York City, November 11-13.

National Academy of Sciences. Berkeley, Calif., November 15-17.

American Physical Society. Chicago, November 26-27.

American Medical Association. Interim session. St. Louis, Mo., November 30-December 3.

"THE GREAT RAVELLED KNOT"

It is the human brain, a vast entanglement of nerve cells. An account of how the brain has been explored to locate areas that are devoted to specific functions

by George W. Gray

THOUSANDS of millions of nerve cells are woven into the texture of the human brain, and each can communicate with near or distant neighbors. Judson Herrick, the University of Chicago neurologist, has calculated that if only a million of these nerve cells were joined two by two in every possible way, the number of combinations would total $10^{2,783,000}$. This is a figure so tremendous that if it were written out and set up in the type you are reading, more than 350 pages of SCIENTIFIC AMERICAN would be required to print it. And we may be sure that the brain has many times a million nerve cells, each capable of groupings of far more than two cells per hookup.

Life has created innumerable patterns in its long climb from the Archeozoic ooze, but none can compare in intricacy of design and virtuosity of function with "The great ravelled knot," as the famous English physiologist Sir Charles Sherrington described it, by which we feel, see, hear, think and decide. This "master tissue of the human body" is perhaps the most challenging of all biological researches.

One can trace the evolution of the master tissue from fish to man, and observe brain part after brain part originate as each succeeding species becomes better adapted to the complex conditions of life on land, more versatile in its capacity for survival—and more intelligent. Similarly, in the developing human embryo the brain forms by the dual process of multiplying the number of cells and increasing their specialization. In the beginning, a few days after conception, certain skin cells are selected as tissue for nerve function. From this microscopic neural tube the spinal cord forms, and simultaneously the hindbrain, midbrain and forebrain develop from the same germinal structure.

It is the forebrain that attains the crowning organization and integration of the nervous system—the cerebral cortex.

SURGEONS at Montreal Neurological Institute operate on patient for brain disorder. Localization experiments are performed at same time.

Beginning as an insignificant segment of the embryonic brain, this gray mantle eventually grows so large that it must fold in on itself in wrinkles to accommodate its expanding surface to the walls of the skull. When fully grown, the cerebral cortex completely covers the brain structures from which it developed. It overshadows and dominates them, taking control of many of their functions. From every nerve cell, or neurone, fibers pass to other neurones, both of the cortex and of the other brain parts. Millions of lines of communication connect one region of gray matter with another, and these in turn with distant organs. By such means the brain is in communication with the lungs, the heart and other organs: with the specialized cells which serve as the receptors of touch, taste, smell, vision, hearing and other sensations; and with the muscles which produce action.

The cortex may be compared to a holding corporation formed to integrate and extend the services of a number of older companies which are housed in the stem of the brain. Under the consolidation the older companies are not abolished. They are continued as useful adjuncts of the more modern organization: to take care of routine activities such as breathing and digestion, to serve as channels of communication, perhaps to be held in reserve as stand-by agencies capable of resuming their former higher functions in emergencies. But the offices of inquiry and foresight, of planning, initiative, the creating of new ideas, the venturing into new projects, are executed by the holding corporation upstairs, and control of the consolidated system is administered there.

ACKNOWLEDGEMENT

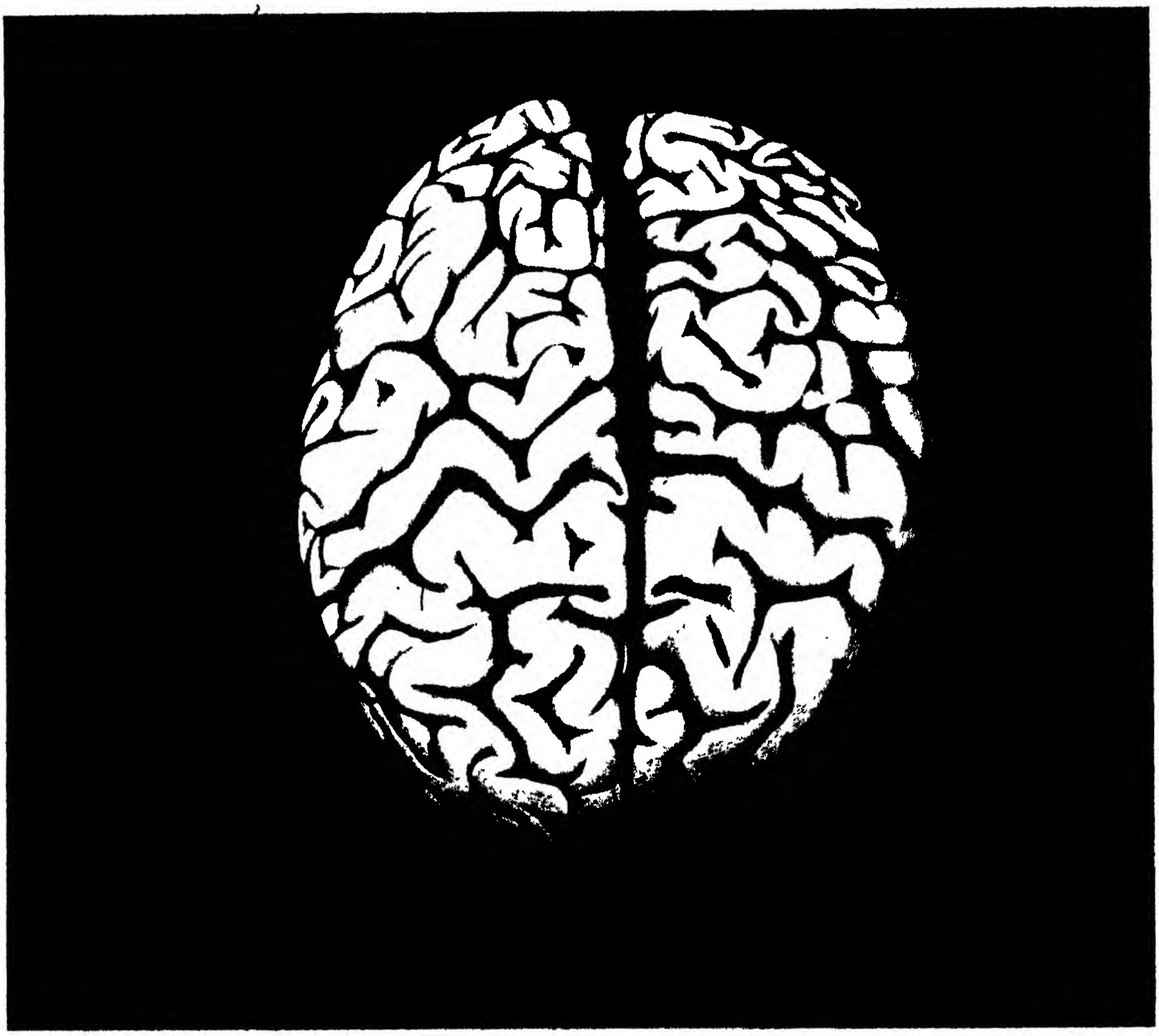
The author acknowledges with thanks the help of the following scientists who were consulted in the preparation of this article: Drs. Philip Bard and Clinton N. Woolsey of Johns Hopkins University; John F. Fulton of Yale; Marion Hines of Emory University; Robert S. Morison of the Rockefeller Foundation; J. M. Nielsen of the University of Southern California; Wilder Penfield and Herbert Jasper of the Montreal Neurological Institute; George L. Streeter of the Carnegie Institution of Washington; and H. A. Teitelbaum of Baltimore.

This roof brain is the supremely distinctive organ of the human species. What goes on within its network of cells makes the fundamental difference between man and brute. The functioning of the cerebral cortex not only distinguishes man from the animals, but more than any other faculty it distinguishes man from man. It marks the fateful difference between the meek follower and the dynamic leader, between the scholar and the artist, between the genius and the moron.

If the proper study of mankind is man, surely the supreme biological interest of man is his brain, particularly the gray cortex of two billion cells without the orchestration of which "there can be no thought, no sweet sonnets of Shakespeare, no joy and no sorrow."

The Cortex

No cortex is an exact duplicate of another, either in the number or size of its convolutions. Indeed, it seems likely that each roof brain is as individual to its possessor as his face, but certain surface landmarks are characteristic of all. The most conspicuous is the longitudinal division into two approximately equal hemispheres (*see drawing on page 28*). Then there is the large fissure that cuts laterally across each hemisphere, originating in the longitudinal division, traveling over the cerebral crest, and continuing down the side of the brain in a direction which if continued would bring it about opposite the ear. This great central fissure (also called the Rolandic fissure) is found in the brains of men, apes and monkeys. Another standard feature which appears also in the primates is the Sylvian fissure. It is the cerebral Grand Canyon, a deep



TOP VIEW OF THE BRAIN shows its principal division into two almost equal hemispheres. The surface is folded into convolutions, probably the product of evolutionary overcrowding of nerve cells within the skull.

gorge which emerges from the bottom of each hemisphere and curves upward and back along the side. The Sylvian fissure perpetuates the name of the 17th-century French anatomist, Franciscus de le Boe Sylvius.

These two prominent depressions provide natural boundaries for subdividing the hemispheres into regions, and almost the first efforts of brain anatomists were directed toward mapping these sections. All that part of each hemisphere which lies in front of the central and Sylvian fissures was designated the frontal lobe. The bulbous rear, which lies under the occipital bone of the skull, was named the occipital lobe. And between these front and rear lobes two others were early laid out: an upper intermediate zone (the parietal lobe, so-called because it lies under the parietal bone of the skull) and a lower intermediate zone (the temporal lobe, below the Sylvian fissure). There is also a limbic lobe, nipped in the cleft between the hemispheres, around the root of the cerebral cortex, where the gray convolutions face one another.

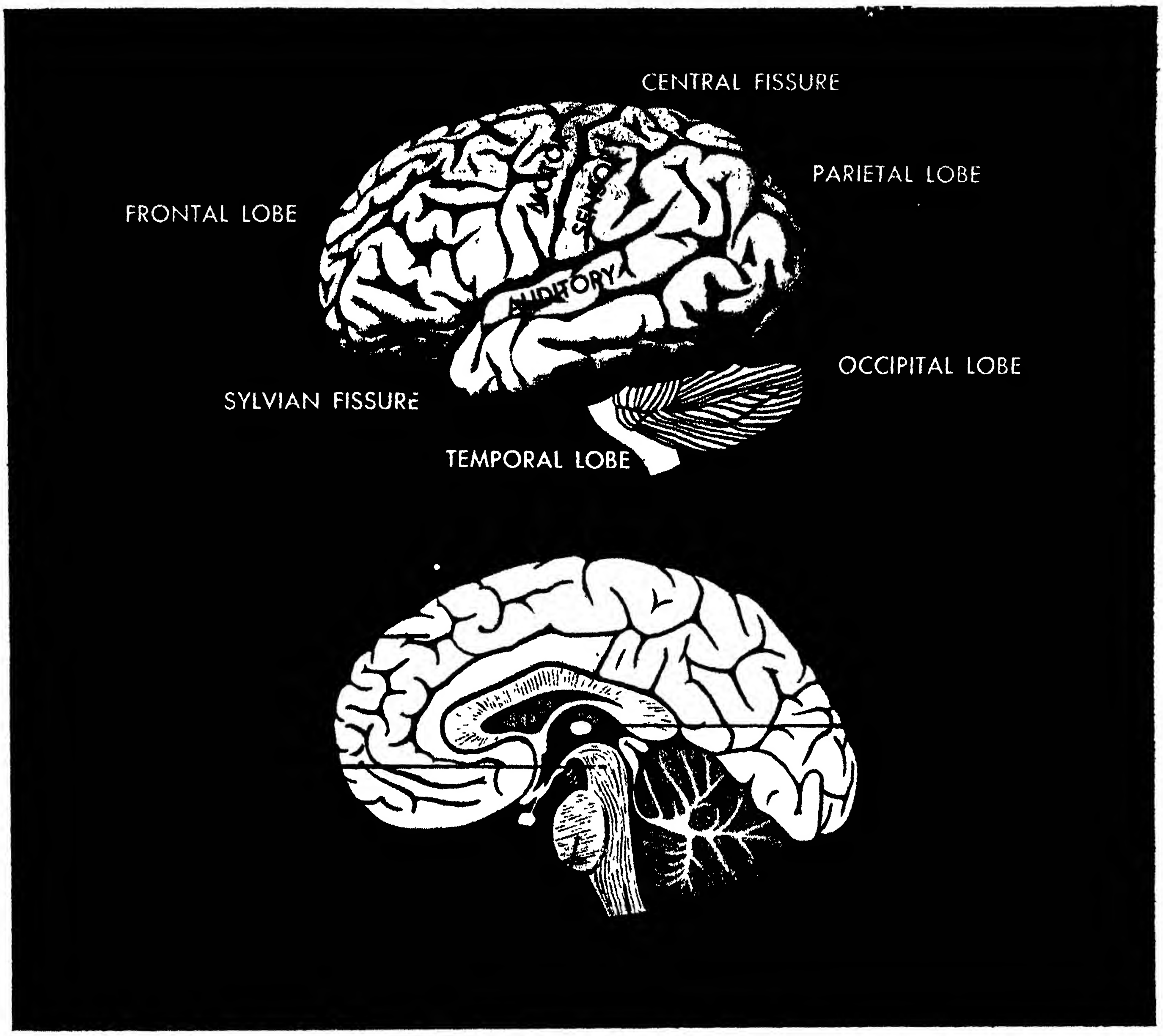
In subdividing the cerebrum into these lobes, the early anatomists apparently had no thought of identifying special functions with each. The accepted idea was that the brain acted as a unit; if by accident or disease one part of the cortex became incapacitated, its faculties were taken over by other parts. This was the almost undisputed view up to the early years of the 19th century.

Then, in about 1805, the Viennese physician Franz Joseph Gall began to teach that the faculty of speech was localized in the frontal lobe, just above the eyes. He had observed that certain fluent speakers had prominent eyes, and decided that this was because their frontal lobes were extraordinarily developed and pressed the eyes forward and downward, with the effect of making the lower lids bulge out.

Others pointed out that there were quite a few orators who did not have prominent eyes and baggy lower lids, but Gall's teaching won many followers. Presently he expanded his idea of localization to include 24 areas of the cortex which he claimed were the control centers for as many faculties, including such traits as cruelty, acquisitiveness, the love of food, mathematical aptitude, the sense of melody, the sense of order and even the sense of time.

Gall gave no attention to such faculties as vision, hearing and other sensory abilities which we regard today as the primary functions of the brain, but was concerned with localizing the moral qualities. Phrenology thus was launched as a "science" by which an individual's character and mental faculties were appraised by measuring the bumps on his head, and for many decades it ran a prosperous course as one of the leading superstitions.

While this preposterous notion was sweeping the world, a few pioneering phy-



ANATOMICAL FEATURES of the brain, described in detail in the text of this article, are indicated in a side view and cross section. Several of the basic functional areas are also lettered on the upper drawing.

sicians were making some real progress in exploring the functions of the brain. It was slow business, for both anesthesia and antisepsis were still in the future, and opening the skull was regarded as equivalent to a death sentence. But there were certain conditions that provided indirect evidence, and one of these was the paralytic stroke affecting only one side of the body.

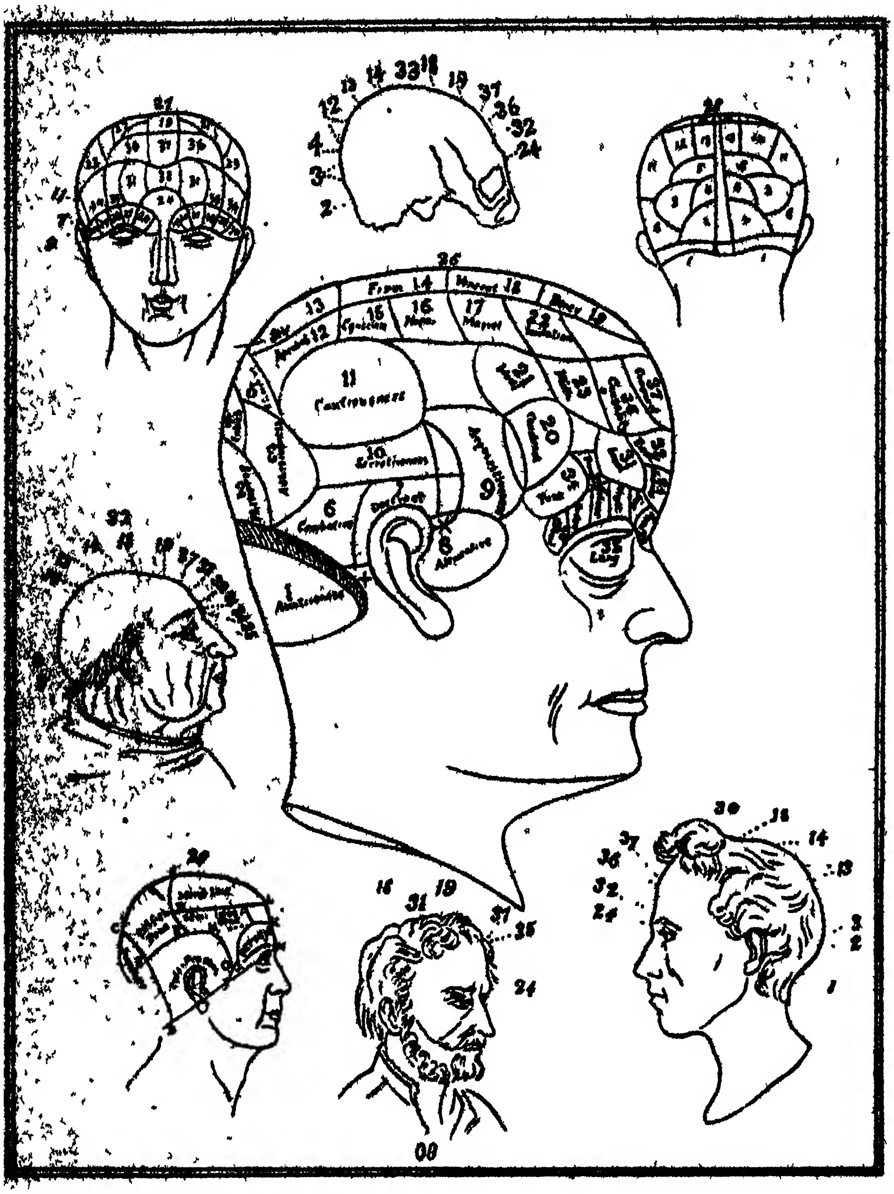
Early Localization

Marc Dax of Paris noticed that whenever a stroke paralyzed the right side of a right-handed person, the patient usually suffered some loss in his faculty of speech. It was known from anatomical dissection that the nervous pathways of the left hemisphere cross over in the brain stem and pass on to the muscles in the right side of the body. From this Dax reasoned that the speech center must lie in the left hemisphere, and that the same injury which paralyzed the control of the muscles also damaged the speech center.

Localization was carried a step further in 1861 when another French doctor, Paul Broca, reported on the post-mortem examination of two paralytics. In each case the patient had been paralyzed only on the right side, and had suffered a serious aphasia which had rendered him speechless. In the autopsies Broca found a serious deterioration of tissue in part of the left frontal lobe. On this evidence he asserted that the brain's control of the vocal cords was not only confined to the left frontal lobe, but that it was localized in a small area at the base of the third frontal convolution.

Broca's fissure and Broca's area have been recognized landmarks of the frontal lobe ever since. Later explorers of the brain, using new tools and improved techniques, have more precisely located the center for the control of speech organs. But it remains in the neighborhood that Broca identified from the scant evidence of his autopsies, and he is appropriately commemorated as the great trail blazer of cerebral localization.

Closely following Broca came the English neurologist Hughlings Jackson, who began to apply the idea of localization to his study of epilepsy, chorea and other brain diseases. By 1869 Jackson had arrived at a clarifying generalization, the astuteness of which is especially impressive because he had no means of checking his speculation by surgery or animal experimentation. Guided entirely by what he observed in patients and found in post-mortem examinations of brains, Jackson announced that there was a primary functional division of the cerebral cortex which cut across both hemispheres. All the *sensory* functions of the brain—its reception of sights, sounds, touches and other signals from sensory organs—were confined to the lobes back of the central fissures, he suggested, while all of its *motor* functions were located in front of them.



PHRENOLOGY, the persistent nonsense that was introduced early in the 19th century by a Viennese named Franz Joseph Gall, ironically was one of the first suggestions of the localization of brain function. Gall, however, did not try to locate real functions of the brain. He localized "moral" qualities.

The first verification of this bold hypothesis came a year later in Berlin when G. Fritsch and E. Hitzig began experimenting with the brains of dogs. By applying weak electrical currents to the frontal region of a dog's right hemisphere, they obtained movements of the left legs. Similarly, by stimulating frontal areas of the left hemisphere, they obtained muscular responses from the right side of the animal. But when the same electrical currents were applied to the back of the brain, no muscle gave the slightest response although the stimulus was many times repeated.

Jackson was jubilant at this experimental confirmation of his idea, and many other neurologists also rejoiced. At last, it seemed, a clue had been found to the general organization of the cortex.

But, it was reasoned, if sensory reception is confined to the back lobes of the brain and motor control to the frontal lobe, should there not be some difference in the cellular structure of the contrasting regions? This led to a large-scale search of brain tissue. It was not until methods of staining tissues for microscopic study were devised that real progress could be made. In particular, three staining techniques were perfected: one by Camillo Golgi in Italy, one by Franz Nissl in Germany, and the third by Karl Weigert, also of Germany. Each stain brought out different details of the tissue, and histologists were enabled to see that the gray matter of the cerebral cortex is built of several kinds of cells arranged in six layers: 1) the surface or molecular layer, a paving of small structures called horizontal cells; 2) a layer of granular cells, small and roundish; 3) pyramidal cells; 4) a closely packed section of granular cells; 5) a layer of more numerous and larger pyramidal cells; 6) a bottom layer of smaller, spindlelike cells.

This six-layer pattern is typical, but in examining segments taken from different cortical regions the investigators found departures from it. The most striking contrast appeared when the area immediately in front of the central fissure was compared with areas to the rear, notably those which have been identified with seeing, hearing and other sensory functions. Microscopic surveys of these sensory areas show that the pyramidal cells of the third and fifth layers are much reduced in size, while the two granular layers are thickly populated with their characteristic small globular cells. By contrast, just the reverse was found in the motor area. Thus not only brain areas but brain cells appear to be consecrated to specific functions. Granular cells function in the reception of sensory messages while pyramidal cells play a corresponding role in transmitting motor signals.

Can we go further? We yearn to know the nature of the nerve impulses that can bring about such an exquisite orchestration of activity. Where and how do they operate so that one impulse is interpreted as a touch, another as a sound, a third as a sight? And where does memory dwell, where are judgment, the imagination, all those higher faculties that we call intellectual, artistic, moral?

No one would claim that more than a beginning has been made toward answering these questions. Some of the answers are more fragmentary than others, but efforts at completing them never slacken, for the incentives to the search are compelling. Fundamentally the incentives are two: intellectual curiosity and the desire to alleviate disease. Not only laboratory investigators but clinicians, following in the train of Broca and Jackson, have been prolific contributors of new knowledge. It has taken many minds, many stratagems, the use of many tools and techniques to chart our present map of the brain.

Electrical Exploration

Today the principal tools for prospecting the brain are electrical. This is only natural, for the gray matter itself is a generator of electric impulses, and the messages that it receives from the sense organs and the directives that it issues to the muscles are all electrical in nature. Electric currents can therefore be used to stimulate the brain in a way that is entirely normal to its function. Conversely, electric impulses generated by the brain and its tributary system of nerves can be picked up and measured to determine the degree of activity in any selected area.

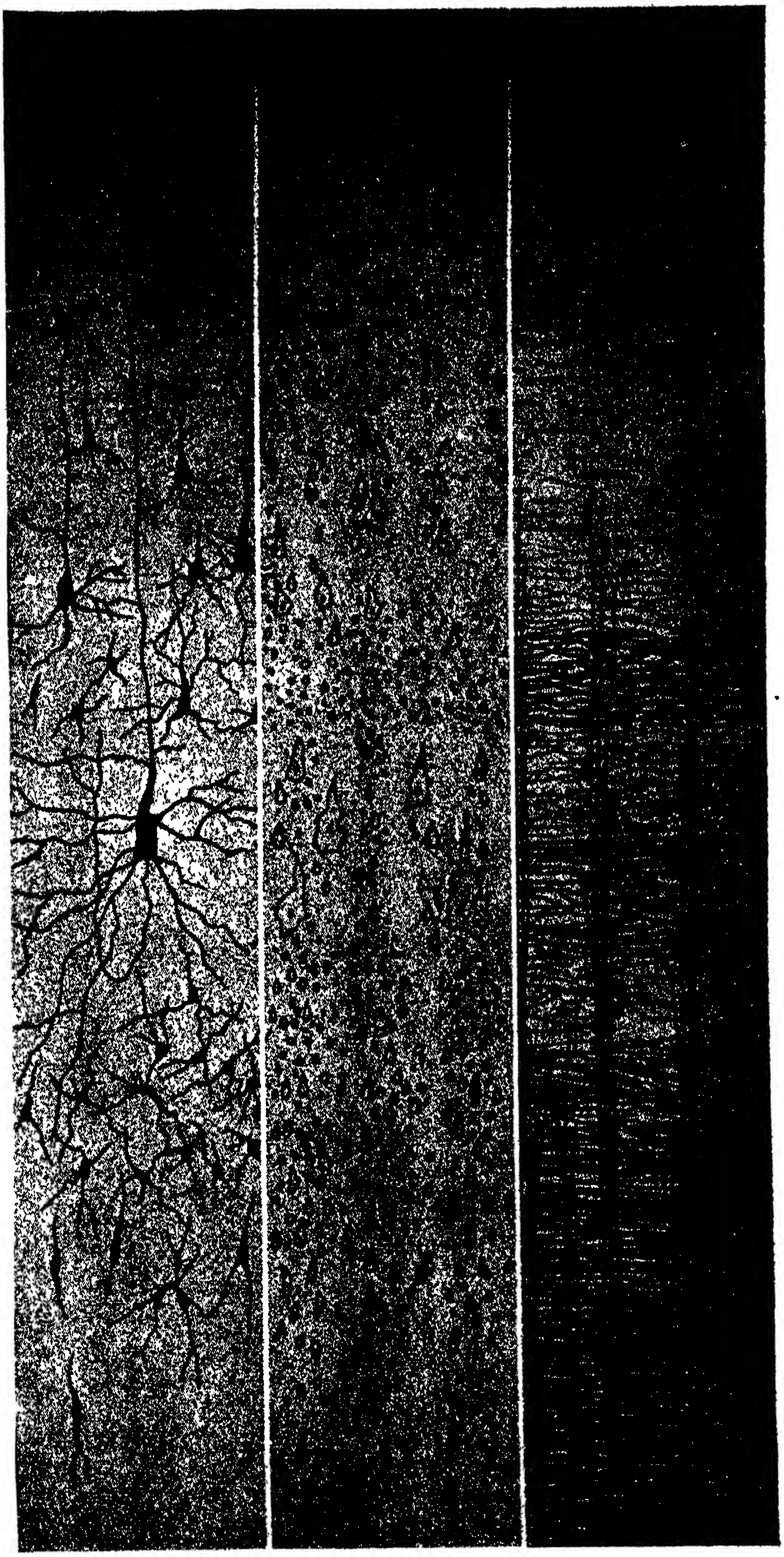
Of the two general kinds of electrical prospecting techniques, one works from the brain outward to the body responses,

and the other from the sense organs inward to the brain. In the first method a delicate electrode carrying an alternating current at low voltage is applied to a selected area of the exposed brain. This technique has been most successful in exploring the motor areas of the cortex. The body-to-brain method, on the other hand, introduces no electric current, but merely picks up the currents that the brain itself generates. In this kind of research the investigator applies an appropriate stimulus to a sense organ, and electrodes moved over the brain determine the destination at which the sensory message arrives. The stimulus may be a slight touch on the bottom of the foot, a flashing light or a sound. The skin, eye or ear then starts a nerve impulse which moves to the cortex, and the area which receives the message announces the arrival by increasing its electrical output. These discharges are so delicate that it was not until the development of the vacuum-tube amplifier that researchers were able to build receivers sufficiently sensitive to measure them.

The vacuum-tube amplifier has been harnessed to this task in two ways: by the cathode-ray oscillograph and by the electroencephalograph. In the electroencephalograph, the feeble electrical discharges picked up from the brain may be amplified millions of times to produce voltages which when relayed through an electromagnet cause a pen to write the pattern of electrical pulsations on a moving paper tape. These brain waves provide an exact record of the fluctuating electrical activity of the brain area upon which the electrode rests.

The principle of the cathode-ray oscillograph is the same, but the manner of applying it is somewhat different. Here the brain currents picked up by the electrodes are similarly amplified, but instead of writing a record on a tape, they deflect a beam of electrons moving in a cathode-ray tube. The moving beam is projected on a fluorescent screen and appears as a quivering luminous line. Whenever the brain area under investigation flares with increased electrical activity, the line pulses in unison with the accelerated discharge. The frequency and amplitude of peaks and valleys in line are measures of the electrical output of the discharging brain cells.

The cathode-ray beam is a more sensitive and precise instrument than the electroencephalograph. It is particularly convenient for surveys of the kind carried on by Clinton N. Woolsey, Philip Bard, W. H. Marshall and their associates at the Johns Hopkins Medical School: exhaustive studies in which a single experiment may last as long as 90 hours. In these surveys, which are made on animals under deep anesthesia, a vibrator may be set to touch the hair of a paw and then, while this repetitious touching stimulus continues, an electrode will be shifted from



ORGANIZATION OF CELLS in the cortex is brought out differently by three staining techniques. The basic six-layer pattern, however, is visible. From top, layers are: 1) small cells, 2) granular cells, 3) pyramidal cells, 4) more granular cells, 5) larger pyramidal cells and 6) spindle-shaped cells.

point to point on the brain. At the same time the researcher or his assistant keeps watch over the quivering line of the oscillograph beam. Sometimes several point positions must be tested before the sudden sharp deflection of the beam announces that here at last is the group of cells where the brain responds to the touch on the paw. After that, the area can be surveyed half-millimeter by half-millimeter, and its boundaries staked out.

In certain studies the electroencephalograph is the preferred tool. It is indispensable when there is need for an appraisal of the background activity of the brain, with its continuously fluctuating pattern of waves. It is also possible to measure the electrical discharges from a number of different areas simultaneously, and electroencephalographs now in use will pick up and record six or more wave tracks, writing them side by side on the same tape for comparison (*see page 38*). Of course the same can be done by a battery of cathode-ray oscillographs working simultaneously, using photography to record the waves.

Surgery has also contributed prodigiously to the localization of brain function. Certain parts of the brain have been removed from animals, and the subsequent behavior of the animals has provided direct evidence of the functions that were related to the lost areas. Performing surgery on human beings is another fruitful source of information. Of course human brains are not deliberately exposed for experimental studies, but when the skull must be opened to remove a tumor, to excise a portion of diseased cerebral tissue or for any other clinical reason, it is often possible to make experimental observations of localization, sometimes to confirm in the human brain what has been discovered in lower animals.

Projection

The meaning that a nerve message conveys does not depend on its source. Whether it is sent by eye, ear, nose, taste buds or organs of touch will make no difference unless the message reaches the appropriate nerve endings in the brain.

"HOMUNCULI" are an actual map of the brain's somatic sensory area and motor area. Here they are projected on facing cross sections of the same hemisphere. Each of the areas outlined by these grotesque manikins

Any nerve impulse arriving at the auditory area and carrying sufficient voltage to discharge its neurones is received and interpreted as a sound, no matter what its origin. Presumably one might hear a smell, if an impulse starting from the olfactory organs should get switched in transit and arrive at the brain's center for hearing.

Certain varieties of focal epilepsy provide dramatic evidence that the brain can generate its own sensations. One victim of this disease reported that just before he was seized with convulsions he always saw rings of light. Another patient's preliminary sensation was sound; he heard discordant noises. There have been cases in which the first sign of an epileptic seizure was a foul smell or a curious taste. These abnormal sensations are produced within the brain by the spontaneous discharge of certain hyperactive cells, and it happened that in one patient the hyperactive cells were connected with the visual area, in another with the auditory area, and so on.

The parts of the cortex that have become specialized for the reception of sensory messages and for the dispatch of motor directives are known as projection areas. For all the motor functions, the projection area is where Fritsch and Hitzig found it by electrical stimulation 78 years ago. In man this means the frontal lobe, just forward of the central fissure.

Facing this motor region, stretching along the rear slope of the central fissure and occupying the adjacent plateau of the parietal lobe, is the somatic sensory projection area, the region where sensations of touch are received from all parts of the body. Far back in the brain, at the very rear of the occipital lobe, is a whitish patch known as the striate cortex, the visual projection area. The upper rear of the temporal lobe, on the lower bank of the Sylvian fissure, is the auditory projection area. Impulses generated by odors pass from the nerve endings in the nose to the olfactory bulb, on the underside of the cortex, and from this diminutive area are distributed to a number of ill-defined areas. Actually the neurologists know very little of the topography and physiology of smell. They know even less of the

is devoted to receiving impulses from the corresponding part of the body (sensory homunculus) or sending them (motor). Parts of homunculi are enlarged or diminished in proportion to how much related part of body is used.

projection area for taste. There is some evidence, according to T. Ruch and H. D. Patton, that this gustatory headquarters may be on the underside of the parietal lobe, in the part known as the parietal operculum.

The sense organs that send messages literally project images of themselves upon the brain. The cochlea, that spiral harp of the inner ear with its coiled membrane of nerve tissue attuned to vibrate over the entire scale of audible frequencies, is the critical organ of hearing—and an image of the cochlea is projected on the auditory area of the temporal lobe. The part of the eye upon which the lens focuses an image of what we see is a tiny section in the center of the retina. This microscopic patch is projected precisely on the visual area of the striate cortex in the occipital lobe, though in an enlarged replica. The brain actually magnifies the picture which illuminates the rods and cones of the retina by several thousand times. Just what sort of images the taste buds and smell organs project would be difficult to imagine. But when one reaches the somatic sensory area and the motor area, there remains no serious doubt or speculation. The image projected here is that of a little man—a grotesque and somewhat dismembered miniature of the human body.

A number of distinguished neurologists, most of them surgeons, have explored the motor and somatic functions of the human brain, and in terms of localization we know more of these two areas than of any other parts of the cerebrum. Horsley, Bidwell and Sherrington in Britain, Keen, Cushing and Ransom in the United States, Foerster in Germany, and others pioneered this field. The most extensive studies have been made by Wilder Penfield and his associates at the Montreal Neurological Institute. With the assent of patients upon whom he performed surgery, Dr. Penfield used electrical prospecting methods to survey the cerebral cortex. Now he has data from several hundred persons.

These accumulated results show that the amount of brain surface related to a specific part of the body is not proportional to the size of the part but to the extent of its use. The area concerned with the hands and fingers looms larger than those related to the feet and toes because we make more use of our hands. The projection of the lips occupies more of the somatic sensory area than all the rest of the head. The brain represents the somatic and motor functions as a kind of dismemberment of the body, with arms and legs joined, torso almost nonexistent, head separated from body, and tongue separated from head. On pages 32 and 33 are drawings of two such "homunculi" from Dr. Penfield's forthcoming monograph *The Cerebral Cortex of Man*. They are used with his kind permission.

This distortion of the body as the brain projects it becomes less exaggerated in animals farther down the scale of evolution. The research group in neurophysiology at Johns Hopkins has studied somatic representation in a succession of animals—monkeys, dogs, cats, sheep, pigs, rabbits and rats. Dr. Woolsey says that it was not until the group studied the rat that it found a brain whose projection gave a reasonable facsimile of the animal's body. The projection on the brain of the monkey is more in one piece than Dr. Penfield's homunculus, but it would be difficult to recognize in the image the animal it is supposed to represent. The cat's image is better assembled, but still is a mutilated edition of its body. The rat, though grotesque, with enormous head and exaggerated lips, is approximately ratlike.

These distortions tell us that each cortex reflects the pattern of the body's daily life. In a pig's brain most of the somatic projection area is devoted to snout; in a spider monkey, with its prehensile tail, there is an enormous tail area; in some dogs it is the olfactory area that holds a position of prime importance. E. D. Adrian of England's Cambridge University reports experiments with a hedgehog in which a current of air was passed through the animal's nostrils. Although the air carried no odor that the investigator could smell, electrical activity flared up over two thirds of the surface of the hedgehog's brain.

Several years ago Adrian was making an electrical survey of a cat's cortex and discovered a second somatic projection area separate from the known area. Shortly thereafter Samuel A. Talbot at Johns Hopkins found that in the cat brain the visual function also had a second projection area. Another series of studies at Johns Hopkins, by Dr. Woolsey and Edward M. Walzl, disclosed that, in addition, the cat has a second auditory area. Since then two-area projection has been demonstrated in several other animals, but in no instance has it been detected for either smell or taste.

Recently Montreal's Dr. Penfield found that man, too, has an extra somatic area. This second projection center is in the parietal lobe, but separate from the better-known area adjoining the central fissure.

Association

Whether man, like the animals, has two projection areas for vision and two for hearing is unknown. Nor have we any inkling of the working of the new-found somatic area, whether it operates subordinate to or coequal with the primary area. Certain experiments with dogs suggest that in the auditory function the second projection area comes into action only when loud sounds are heard; they also indicate that this area gives a less detailed image of the sound pattern than that projected on the primary hearing centers.

The sights, sounds, touches and other signals that the projection areas receive are a miscellany of random information, every item of which would be endlessly new, bewildering and useless were it not for the functioning of other areas of the roof brain. The burned child avoids the fire, but not because of the sharp signal of pain received in the somatic sensory area. It is the association that teaches the lesson—the association of pain with the sight of fire, perhaps with the sound of a warning scream, with the muscular action of drawing away, and so on.

The brain must have memory in order to relate the information of the moment with that of the past and to recognize its significance. This means millions of functional correlations, countless hookups of sensory centers with one another and with motor centers, repeated exchanges of data for analysis, comparison and synthesis. These elaborative functions of the cortex are performed by the association areas.

It would be meaningless to say that association areas are more important than projection areas, for without the latter, if we can imagine such a thing, the cortex would have no information about the outside world and no means of voluntarily controlling the body's muscular action. But even though it be indispensable, projection is the lowest level of cortical activity. As we go down the scale of animal intelligence we find the proportion of brain devoted to projection areas growing greater, and that occupied by association declining. In the rat almost the entire cortex is given over to projection, says Dr. Woolsey, "and it is difficult to see where there is any room for association areas."

In man more than three fourths of the roof brain is occupied by association areas. For example, that patch of striate cortex at the rear of the occipital lobe, the sensory area upon which the retina projects its images, is surrounded by an association area known as the parastriate cortex. Encircling this, and so closely interwoven that the boundary is obscure, lies a second visual association area, the peristriate cortex. It is possible to trace fibers connecting these three. In addition, fibers from the peristriate area run beneath the central fissure to connect with parts of the frontal lobe. Thus the seeing department of the brain, though housed in a small area in the back of the occipital lobe, has connections which link it with much of the roof brain. Even if we consider only the parastriate and peristriate surfaces, they have many times the area of the visual projection center.

An injury that destroys the visual projection area in both hemispheres causes total organic blindness—cortical blindness, the neurologists call it. If the injury is confined to the parastriate (first association) area, the victim can see but is unable to recognize or identify what he sees. This is mind blindness, a form of agnosia (loss of recognition). If it is the

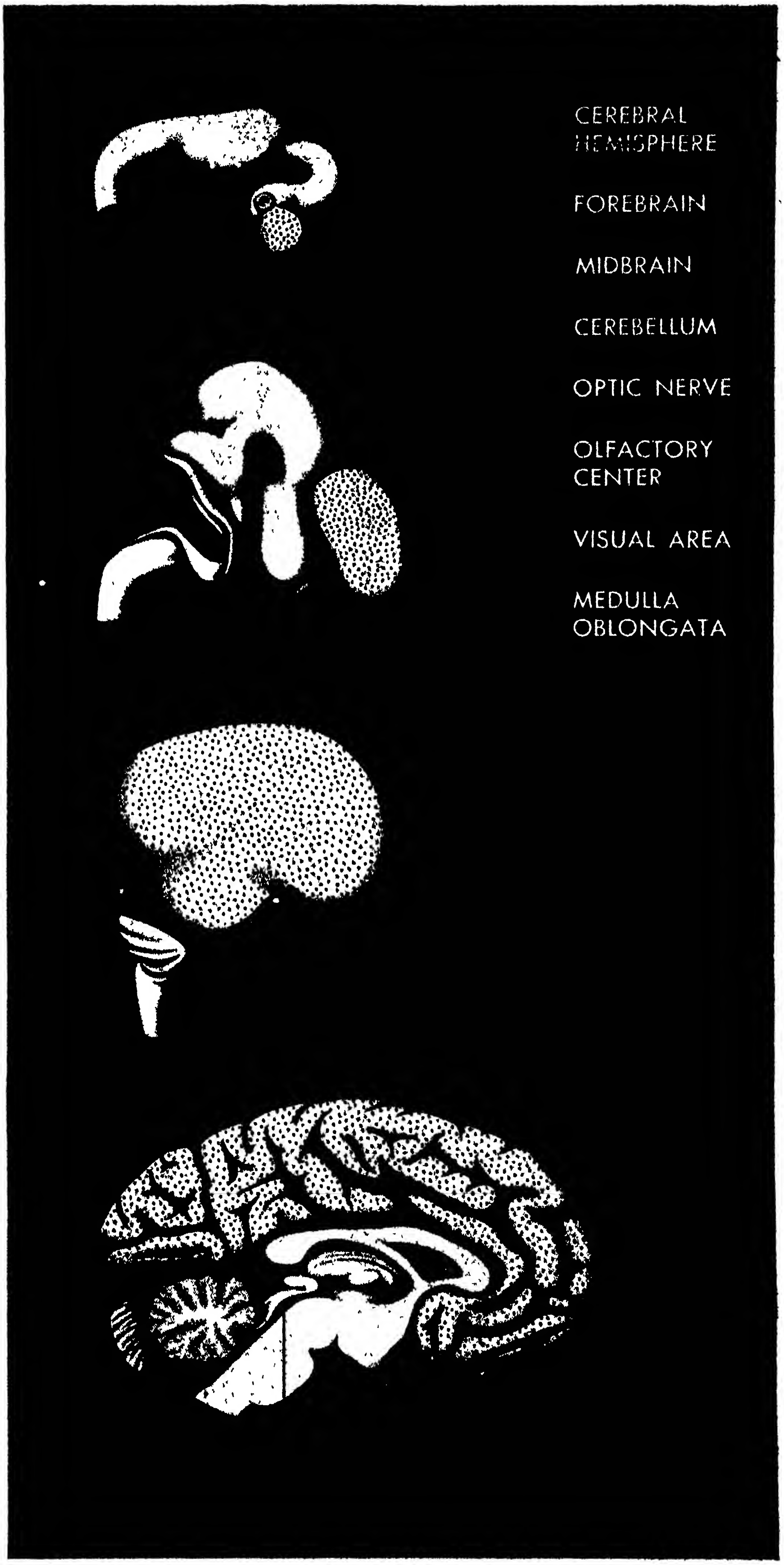
peristriate (second association) area that suffers the injury, the mind may have no difficulty recognizing objects but cannot recall their appearance when they are not in view. This kind of disability was early recognized in disturbances of the use of language, when the patient was unable to associate the printed or written word with any meaning. So the loss of function of the second visual association area is commonly called word blindness, one of the so-called sensory aphasias (loss of speech).

During a poliomyelitis epidemic in Los Angeles, a hospital nurse fell victim to the infection. She escaped paralysis, but in about three weeks it became manifest that her visual faculty had been damaged. "Why are the nurses wearing black uniforms?" she suddenly asked an attendant one day. Tests showed there were other things besides the starched white uniforms that she failed to recognize.

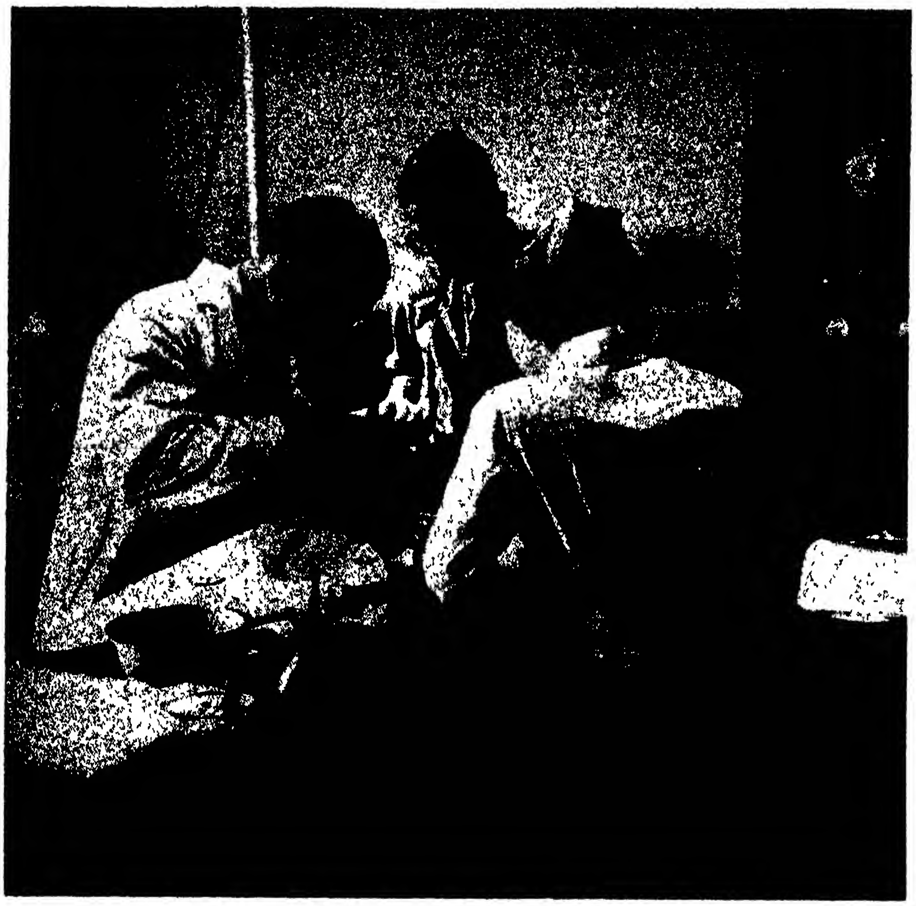
"When we asked her to read," relates J. M. Nielsen, who reports the case in his book *Agnosia, Apraxia, Aphasia,* "she claimed she could not see. When an O about ten centimeters in height was written for her, she peered at it and said we were holding it too close. The position was corrected, after which she said we were holding it too far away. She kept turning the paper about and peering in various directions, but was unable to read it. She then traced it with her finger (proof that she could see) and immediately read it correctly. Other letters were then tried, and it was found that she could see even small letters and could read complete sentences if she was allowed to trace the letters with her fingers. She even began to complete words before she had quite finished tracing them. Here it should be noted that she traced them by arm, not finger, movements. On certain days she did not recognize colors at all; on other days she recognized some of them."

Keys on a ring were exhibited to the nurse; she shook her head, but as soon as the keys were rattled she said, "Keys." When a saucepan was exhibited, her mind was again a complete blank, but when the pan was tapped with a spoon her face lighted up with recognition. A watch was seen only as "something bright," but when the ticking object was placed to her ear she murmured, "Watch." It was not until a piece of paper was crumpled, producing a crackling sound, that she was able to identify it. Looking at an orange meant nothing, but when the nurse smelled it, recognition was immediate.

The agnosia here was of the first order, mind blindness, caused by a disturbance of the functioning of the parastriate cortex. There was no disability of hearing, smell or touch, no disorder of the motor faculties, so the case was relatively simple compared with some complications in which mind blindness is combined, for example, with mind deafness, or, as sometimes happens, when an agnosia of one



DEVELOPMENT OF THE BRAIN in the embryo of man is a history of the organ's evolution. At top the forebrain is an insignificant part of the whole. At the bottom it comes to dominate the more primitive parts. A few anatomical and functional features are repeated as points of reference.



CAT BRAIN IS EXPLORED with probes that pick up electrical activity deep in the cortex. Activity is recorded on the face of the cathode-ray tube at the upper right. Animal is deeply anesthetized before experiment.

AID TO EXPLORING the cat's brain is the stereotaxic apparatus. This makes it possible to insert probe and determine its position with great accuracy. Experiment was performed at Montreal Neurological Institute.

order of association is combined with an aphasia of another order.

Various brain injuries have disabled the other senses in a manner corresponding to the cortical blindness, mind blindness and word blindness of the visual area. From this we infer that each sense has its successive areas of association, although the actual topography of the areas is not completely known for the visual faculty and is even less definitely mapped for the others.

Sometimes the effect of injury is an amnesia, the disability of forgetting. Dr. Nielsen tells of a man who periodically forgot the left side of his body. He washed his face only on the right side and bathed only his right arm and leg. When his wife called attention to this curious favoritism he was highly amused, admitted that he did have limbs over there on the left, and dutifully bathed them. But when he came to dress, again he forgot his left side and tried to put clothes only on the right. This amnesia became progressively worse until a brain operation was performed and a tumor in an area of the parietal lobe, near the somatic sensory region, was disclosed.

The motor side of the cortex, in the frontal lobe, also has its association areas. Broca's area, mentioned earlier in this article, is one of these. This association area for the elaboration of speech function is found normally only on one side of the brain: in the left hemisphere of right-handed persons, in the right hemisphere of the left-handed. Nearby is the association area for certain motor functions controlling manual dexterity. Anthropology teaches that the complicated business of developing and using language is closely related to using tools and developing other skills of the master hand. Some suggest that the earliest language may have been a system of signaling with the hands. Broca's area is closely connected with other association areas of the motor side of the cortex and also with areas on the sensory side, *e.g.*, with the visual area (for reading language), the auditory area (for hearing language) and possibly with the somatic area as well (for correlations essential to writing).

Damage to the motor association areas or their connecting fibers may bring two kinds of result: 1) apraxia; 2) motor aphasia. In the first instance the individual is unable to perform purposeful movements—he suddenly finds he cannot tie a shoelace or thread a needle or guide a pen. Told to sign a letter, he cannot do it, although he wrote the letter without difficulty. Apraxia is the motor equivalent of sensory agnosia—a disability of the first order of motor elaboration. In motor aphasia the ability to speak is affected, just as in sensory aphasia the subject no longer understands the significance of what he sees, hears, or touches. In other words, when motor association areas of the first order are damaged, purposeful movement is impaired; when those of the

second order are damaged, speech is impaired. Broca's area appears to be an elaborative zone of the second order.

Loss of speech is the most frequently encountered symptom of higher functional impairment, and it may take many forms. Sometimes the disability seems a mere eccentricity, like that of the patient reported by H. A. Teitelbaum of Johns Hopkins who could read the digits 5 and 7 but not 57. Complete speechlessness is the extreme form, though usually the victim can say a few simple words like yes or no. Sometimes the speech is meaningless jargon. It is quite common for aphasic patients to say the same word over and over again, and often it is a word they don't want to say, while at the same time they can't form the word they do want to say. The writer knew one man who could recite poems, quote Shakespeare and sing songs without skipping a syllable, and yet was unable to use the same words in conversation.

These disorders of association rarely occur as uncomplicated conditions, the effects of which point unerringly to specific areas of disturbance. Often there is a mixture of symptoms that confounds all our efforts to portray the great ravelled knot as a compartmented organization. The roof brain is not that simple.

			MOTOR	
			NORMAL	DEFECTIVE
Integrations of little complexity	Primary Sensation	Anesthesia	Voluntary contraction	Paralysis
Integrations of greater complexity	Recognition	Agnosia	Purposeful Movement	Apraxia
Integrations of greatest complexity	Understanding	Sensory aphasia	Meaningful speech	Motor aphasia

NORMAL AND DEFECTIVE behavior of brain areas are related in chart. Both projection areas (like those shown on pages 32 and 33) and association areas are listed. Exact location of many of the latter is still unknown.

The Silent Areas

The frontal lobes are the largest segments of the brain. After mapping the extensive motor areas in front of the central fissure and other motor association areas even farther forward, the neurologists are left with considerable territory still to explain. This prefrontal region, the prow of the brain, overhanging the eyes like a gray canopy, does not respond to electrical stimulation. For that reason it has been called the silent area. From classical times it was regarded as the dwelling place of memory and of the higher intellectual faculties--the seat of intelligence.

But a hundred years ago a quarryman in Vermont sustained a violent injury to his frontal lobes and did not seem to suffer a serious impairment of intelligence. The quarryman had drilled a hole in a ledge of stone, and, after laying in the gunpowder, was tamping it with a crowbar, when suddenly the charge ignited. The crowbar shot upward into the man's cheek, passed into his skull, and tore an ugly wound in both frontal lobes. Someone rushed to his assistance, pulled the steel out, and by a miracle the wound healed. Months later the quarryman returned to work. Although he was not able to take on his former job as a foreman, he proved to be entirely capable as a worker. His memory was good, his skill as a stoneworker seemed about the same as before the accident, but everyone associated with him noticed a marked change in his behavior. He was profane in speech, indifferent to the interests of others, careless of his obligations—traits which the neighbors were disposed to overlook, remembering that he had passed through a nerve-racking experience.

Numerous frontal-lobe experiments have been attempted with animals, and one that will go down in history was begun at the Yale Medical School in 1933. In the physiological laboratory there, John F. Fulton and Carlyle Jacobsen were curious to see what effect removal of the prefrontal region would have upon two chimpanzees. From October to the following March the two apes Becky and Lucy were put through intensive training. Then a surgical operation was performed removing the prefrontal region of one hemisphere in each animal. The operation did not change their behavior appreciably. After the wounds healed the chimpanzees were subjected to intelligence tests again and their responses continued as before. In June another operation was performed, removing the remaining prefrontal region from each. When Becky and Lucy were given the tests this time, Fulton and Jacobsen found that a radical change had taken place. The tantrums that used to flare up after the chimpanzees had made the wrong choice and had been denied food or other rewards no longer appeared. "If a wrong choice were made now," said Dr. Fulton, "the animal merely shrugged its shoulders and went on doing something else."

Fulton and Jacobsen reported the experiment to a meeting of medical men in London in 1935. At the close of Fulton's address Egaz Moniz, a neurologist from Lisbon, proposed: "Why wouldn't it be feasible to relieve anxiety states in men by surgical means?" Dr. Fulton admits that the suggestion of so immediately applying the result of an animal experiment to the treatment of human illness rather startled him. But within a year Moniz had enlisted the cooperation of a surgeon, Almeida Lima, and together they had operated on 50 hopeless mental patients in Portugal. Dr. Lima did not remove any part of the cortex, but severed the pathways between the prefrontal region and the thalamic center in the brain stem. Because it was the fibrous white tissue that was cut, he called the operation leucotomy (from the Greek *leukos*, meaning white). The following year, the first leucotomy in the U. S. was performed by Walter Freeman and James W. Watts in Washington. The method has since been taken up by other surgeons and close to 2,000 persons in North America have been operated on by leucotomy or related techniques.

This severing of the connecting fibers apparently releases the "new" brain of the prefrontal region from the emotional dominance of the "old" brain of the cerebral stem—though we have no knowledge of the nature of this emotional dominance. Whatever the mechanism, there have been amazing transformations of violently insane persons into seemingly normal ones. Sufferers from involutional melancholia and other dementias associated with middle age, and even schizophrenics, have benefited. Some leucotomies are unsuccessful, but it is claimed that better than 60 per cent of the subjects have shown improvement following the operation. Adverse personality changes also result, however, and efforts are now being made to determine the total effect of leucotomy, weighing the good—the relief of psychotic symptoms—against the bad—the deterioration in personality. Among these personality changes are intensified selfishness, indifference to moral obligations, failure to foresee the consequences of acts, gauche manners and emotional instability.

Wars and accidents have provided thousands of cases of men with brain injuries, as have surgical operations for removal of tumors and other diseased frontal tissue. While examining battle-wounded men, Kurt Goldstein of Montefiore Hospital in New York was impressed by the lack of imagination and by the defective judgment found in many with frontal-lobe injuries. Dr. Goldstein observed that such a man, so long as he was confronted with concrete situations with which he had had experience, seemed perfectly normal, but when the situation was new and a method of meeting it had to be improvised, the patient's deficiency was strikingly apparent; he was unable to assume an attitude toward the abstract.

This failure to draw inferences from

abstractions was brought out by a test used by Gösta Rylander of Stockholm in a follow-up study of 32 Swedish cases. The test (only one of many used) quoted a series of proverbs and asked what each meant. For example, "The pitcher which goes oft to the well gets broken at last" is universally familiar, but many of these men and women who had lost part of their prefrontal cortex interpreted the parable quite literally and found it incongruous. The response of a clergyman, the most highly educated member of the group, was, "But a pitcher can't possibly walk."

ELECTROENCEPHALOGRAPH curve is compared with standard chart by technician at the Montreal Neurological Institute. Longer strip above is inscribed by four pens connected by wires to contacts on patient's scalp.

After reading "A blind hen may also find a seed," he laughed hilariously and retorted, "Not if she can't see."

Perhaps this Swedish clergyman's case gives as striking an example as may be found of the characteristic effects of prefrontal injury. The patient was 53 years old, graduate of a prominent theological college, minister of an important parish. A recognized leader, he possessed marked organizing talent, and as a preacher was known for the thoughtful content of his sermons and their wealth of figurative expression. He was an omnivorous reader, modest of manner, of heart-warming friendliness, but extremely conservative in theology. In mid-life, the man suddenly began to fail mentally; his memory became defective; he had occasional lapses of consciousness, even mild epileptic attacks. A surgical operation showed a large tumor, the removal of which necessitated cutting out a sizable prefrontal section. Two and a half years after the operation, Dr. Rylander examined the clergyman. He was still good-tempered as a rule, but sometimes he flew into a sudden rage or broke into tears over trifles. He was given to making facetious, shallow and often tactless remarks. He never opened a book now, but he read newspapers and was interested only in current events. He found conversation in a group difficult to follow, but he spoke readily with one individual. He avoided tasks involving concentrated attention, ignored responsibility, left all planning and execution of plans to his wife. When invited to preach he pieced together an old sermon. His bishop did not dare return him to his former charge, but waiting for a new assignment did not seem to bother the minister any more than the fact that his allowance for leave of absence would soon be reduced. "The patient could by no means be called mentally deteriorated in the ordinary sense," reported Dr. Rylander. "He seemed still to have a good command of his own sphere. He could converse well on religious subjects, showing good judgment and an ability to throw light on different problems." But in intelligence tests, he attained an I.Q. of only 72, as compared with 110 for another clergyman used by the neurologist as a control.

Summing up his observations of the 32 individuals, Dr. Rylander finds that emotional changes occurred in 30, changes in volitional and psychomotor activity in 22, and intellectual changes (mainly involving the higher faculties) in 21. He concludes that while the changes usually do not destroy the subject's ability to lead a normal social existence, they can be disastrous "to persons doing qualified intellectual work."

A more extensive and prolonged study of effects of prefrontal loss is reported in the recently published *Brain and Intelligence* by the psychologist Ward C. Halstead. Halstead has been directing a laboratory for the investigation of neurological patients at the University of Chicago Clinics since 1935. He has examined 237 persons, including brain-injured patients, psychiatric patients and normal individuals used as a control group. Defining biological intelligence in operational terms of four basic factors, the psychologist has carried each of his subjects through an extensive series of tests to measure individual ability in each factor. The findings of his 12-year inquiry may be briefly summarized as follows: that biological intelligence is represented throughout the cerebral cortex; that its representation is not equal throughout; that it reaches its maximum in the cortex of the frontal lobes. Dr. Halstead concludes that "the frontal lobes, long regarded as silent areas, are the portion of the brain most essential to biological intelligence."

But we are still in a realm of speculation so far as a completely consistent picture of brain organization is concerned. Some authorities cling to the idea that learning, intelligence, imagination and the other intellectual faculties are a function of the brain-as-a-whole—and certainly there is evidence for such a view, along with the evidence for localization. Despite the substantial progress that has been made in identifying certain unmistakable areas (of which this article is a brief review), the cortex remains a vast entanglement of interconnecting lines and nodes. It is these interconnections that present the supreme enigma of neural organization. Whether the brain of man is capable of unraveling and comprehending its own complexity is, of course, a question. The very existence of that unresolved complexity constitutes a challenge. Physics, chemistry and mathematics, of which only limited use has been made by neurology up to now, will undoubtedly become major partners in the grand-scale teamwork of research that is ahead.

George Gray is author of the books Frontiers of Flight *and* Science at War.

ELECTROENCEPHALOGRAM IS MADE with patient inside a shielded room. Electroencephalograph apparatus is in foreground. This method of recording brain activity is somewhat less sensitive than the cathode-ray tube shown on page 36. It is standard, however, for diagnosing epilepsy and locating brain damage.

ORIGIN OF THE ICE

Eccentricities in the motion of the earth may account for the glacial epochs of the past, thus assuring others for the future

by George Gamow

IF A STONE AGE traveler had ventured to explore the North American Continent 25,000 years ago, he would have encountered some frightening contrasts of scenery. He would have found all the southern part of what is presently the U. S. covered by thick forests of boreal spruce and pine. On his way north he would have been stopped by a great wall of ice extending roughly from New York City to the state of Oregon. This icy barrier, which probably looked very much like the one sighted today by explorers approaching the coast of Antarctica, was the southern fringe of a thick sheet of ice descending from the highlands of Greenland and the northern Rocky Mountains. Its glittering surface covered the entire area of Canada and a good half of the U. S.

The scenery was much the same in the northern part of the Eastern Hemisphere

GLACIER descending from mountains of the Chugach Range in Alaska is a remnant of the great ice sheet.

MAXIMUM EXTENT of the ice is indicated by the areas on map. Projection shows glaciation of both Eastern and Western Hemispheres. White areas are a composite of the glaciations of the last 600,000 years. Principal

Ice sheets descending from Scandinavian mountain ranges completely covered the British Isles, the North Sea, northern France and Germany, and a good part of European Russia. Siberia, curiously, was largely spared the enslavement of the ice. Although the Siberian climate during the glacial epoch must have been as severe as it ever has been, the glaciation there was less extensive than that of Europe and North America. This was undoubtedly due to the absence of high mountains, for it was the flow of accumulated ice from mountains that accounted for the vast glaciers of other regions.

As the centuries rolled by, the ice sheets gradually melted away and retreated to the north. At present only isolated patches are left to remind us of the frozen past. Among the last strongholds of the retreating ice are Antarctica and the island of Greenland, which is still covered by a solid ice sheet several thousand feet thick and 700,000 square miles in area. Other remaining ice patches are the Columbia Ice Field of 150 square miles near Banff National Park in western Canada, and numerous smaller glaciers along the crest of the Rockies.

The retreat of ice is still in progress. The existing glaciers are becoming smaller and smaller. Foresighted rangers in the U. S. Glacier National Park, anticipating their complete disappearance, are already assuring visitors that the Park will remain an excellent vacation resort even after the glaciers are gone.

Our information about the glaciations of the past, like all other information about the history of the earth, is obtained chiefly from geologic deposits, in this case those left by the retreating ice sheets. These deposits, which were left in the lakes that lay along the southern edge of the retreating ice sheet, clearly show layers which apparently correspond to the passage of summer and winter. During the summer, streams originating in the melting ice carried down a coarse, light-colored silt. Above this a darker layer of fine clay was deposited during the winter months, when the lakes were frozen and the streams were quieter. Counting the number of such layers in the deposits left in the wake of the ice sheets, it is possible to make a good estimate of how fast the ice was retreating, and how long ago the glaciation was at its maximum. Using this method, geologists have estimated that the last ice age reached its high tide 25,000 years ago.

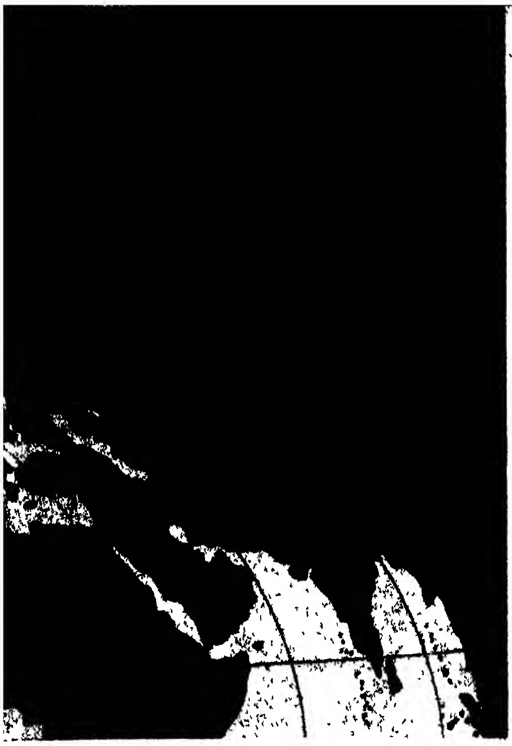
A STUDY of still deeper deposits indicates that the ice advanced and retreated several times: geologists count at least four major ice periods during the last 600,000 years. These periods, named for the Swiss river valleys where their deposits were first studied, are: the Günz glaciation, from approximately 600,000 to 550,000 years ago; the Mindel glaciation, between 480,000 and 430,000 years ago; the Riss glaciation, between 230,000 and 180,000 years ago; and the Würm glaciation, which has not entirely receded even at the present time.

All these advances and retreats of ice took place after man had begun to walk the earth. The skeleton of an apparently human creature has been found in deposits corresponding to the Günz glaciation, and later human types witnessed the last major advance of the ice sheets.

What caused these extensive glaciations of the past? Is there any reason to expect that future generations of humanity will be forced to move south by another advancing ice sheet which will blot out the flourishing northern cities?

Since all life and motion on the surface of the earth is impelled by the radiant energy of the sun, it is natural to assume that the major changes of climate that characterized the ice ages were due primarily to variations in the amount of solar heat falling upon the surface of our planet. There are two ways in which such variations might have occurred: 1) actual changes in the intrinsic brightness of the sun; 2) changes of the earth's orbit that would take our globe closer to or farther away from the sun during the various epochs of geologic history. In the light of the modern understanding of stellar evolution, the first of these possibilities does not seem likely, for the sun is known to be a well-balanced heat-producing engine, and there is no reason to expect that its intrinsic brightness would change appreciably during the interval of time covered by the glacial ages. On the other hand, it is an established fact that the distance of our globe from the sun is subject to irregular changes.

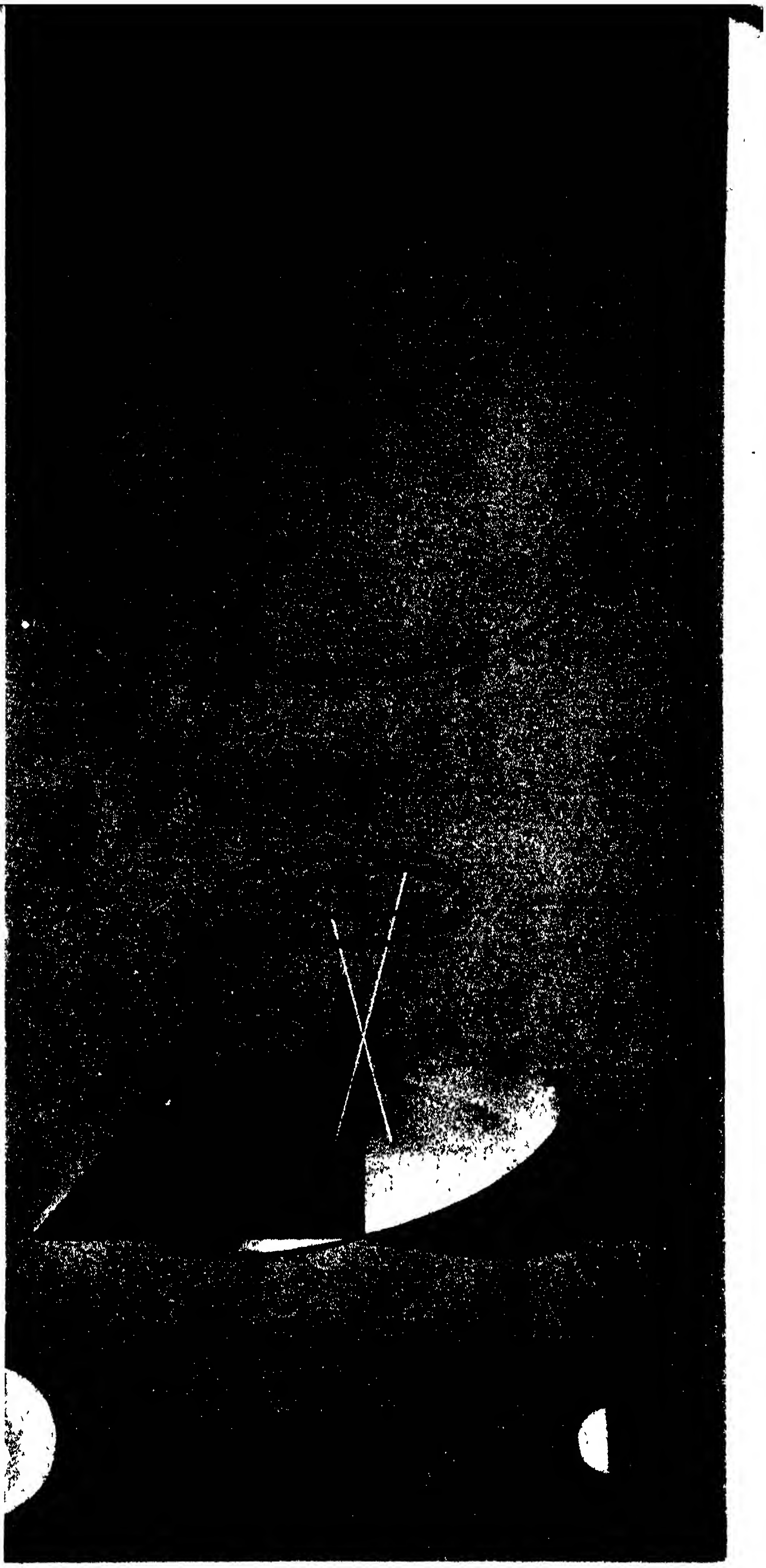
It is generally known that the earth moves around the sun on a slightly elongated elliptical orbit. It is somewhat closer to the sun about Christmas time, somewhat farther away toward the end of June. Hence the winters in the Northern Hemisphere, coming when the earth is closest to the sun, are at present milder than those in the Southern Hemisphere, and the summers are somewhat cooler. This state of affairs is subject to periodic change, however, due to the phenomenon known as the "precession of the equinoxes," which was first discovered by the Greek astronomer Hipparchus and was



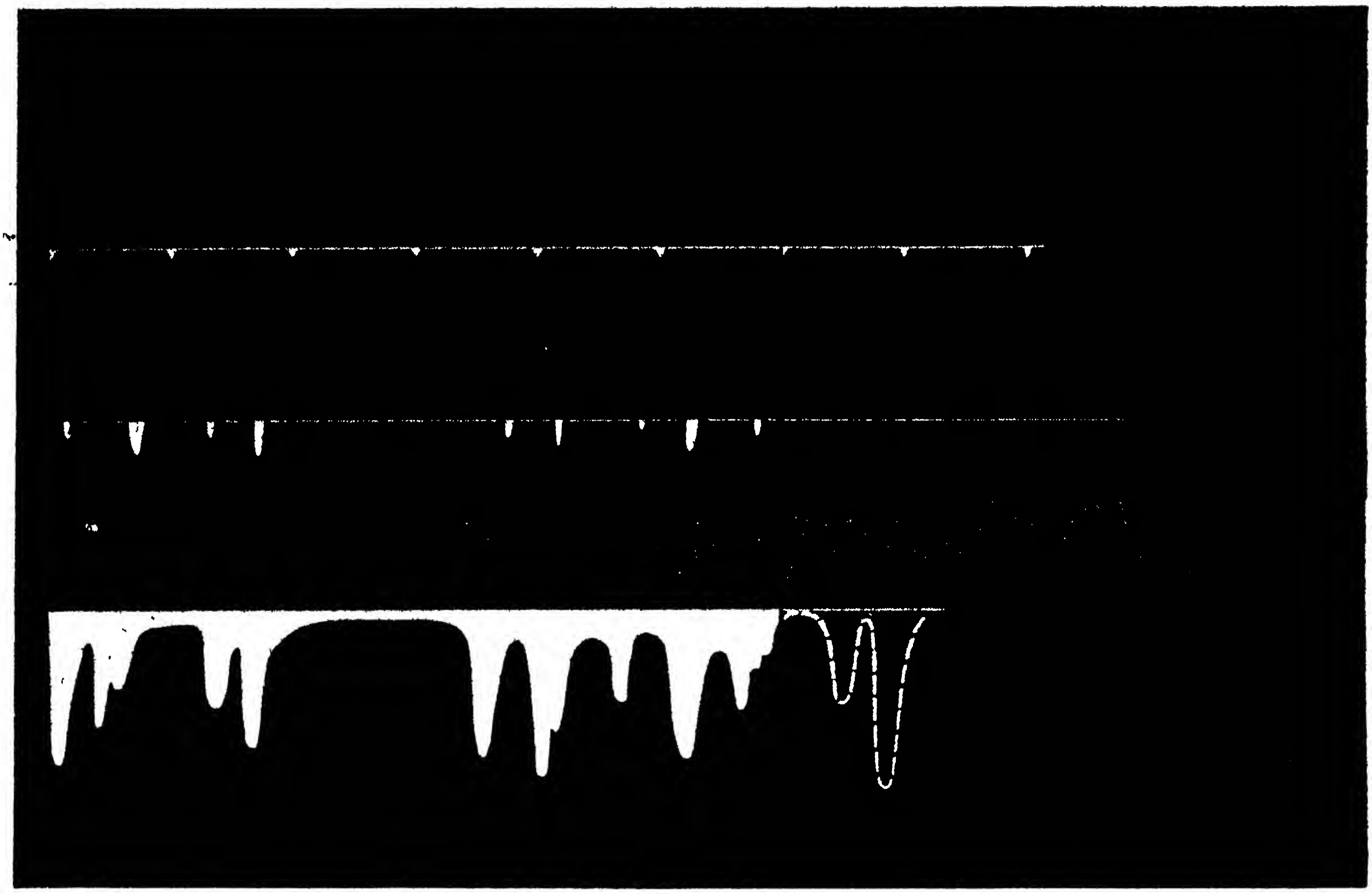
remnant of the last ice sheet is the glacier that today covers Greenland.

later explained in terms of universal gravity by Isaac Newton. The point is that the earth is not quite spherical but has the shape of an ellipsoid, bulging out around its equator. One can show that the gravitational forces of the sun, acting on this equatorial bulge, tend to straighten out the rotational axis of the earth, and to make it perpendicular to the plane of the earth's orbit. But the earth is like a spinning top, and it is well known that any attempt to straighten out the rotation of a leaning top results only in making its axis move slowly in a circle around the perpendicular. In the case of the earth, this period of precession is some 26,000 years. At present the earth is tilted in such a way that at the point in its orbit when it is closest to the sun the Northern Hemisphere is turned toward the sun. Thirteen thousand years from now the earth will be tilted in the opposite direction, and northern winters will be more severe than southern ones.

If the earth were the only planet in the solar system, its motion along its orbit would be completely undisturbed, and it would have moved with monotonous regularity through the entire period of geological history. However, the presence of other planets exercising their gravitational pull on our globe forces the earth to move along a slightly different orbit in each successive revolution around the sun. Because the masses of the planets, even of such big ones as Jupiter and Saturn, are very small as compared with the mass of the sun, their effect on the earth's orbit is slight and shows itself only over a period of many thousands of years. But a mathematician can easily work out the problem of the earth's motion under the action of the combined pull of the sun and the



MOTIONS OF THE EARTH vary in geologic time. Drawing A shows eccentric path described by center of the earth's orbit about the sun over 200,000 years. Three sample orbits about the center are on a much exaggerated scale. Drawing B shows movement of earth's axis and plane of its orbit during the same period. Drawing C illustrates how the tilt of the axis causes a seasonal variation in sunlight falling on the Northern and Southern Hemispheres.



CORRELATION of astronomical and geological data lends support to the theory that the glacial periods have resulted from variations in the earth's motion. Advance of the glaciers plotted at bottom is on the same time scale as astronomical curve at top. Recurrence of eccentricities makes possible prediction of new ice ages.

planets. The branch of astronomy known as celestial mechanics permits us to calculate with great precision the deformations of the earth's orbit for hundreds of thousands of years in the past and for hundreds of thousands of years to come.

Some results of such calculations are shown schematically on a rather exaggerated scale in the diagram on page 43. The earth's orbit fluctuates considerably: it was rather elongated about 100,000 years ago, shrank to a more nearly circular form around 50,000 B.C., became elongated again in 20,000 B.C., and now is shrinking again. It will reach the least elongated shape about 20.000 years hence. It is obvious that greater elongation of the earth's orbit must result in pronounced differences among the seasons, whereas smaller elongation will tend to lessen this difference.

The gravitational pull of other planets also results in variations of the angle between the earth's axis and the plane of its orbit. As we have noted, the inclination of the earth's axis to its orbital plane is responsible for the phenomena of summers and winters, since in its rotation around the sun our globe alternately turns its Northern and Southern Hemispheres toward the sun. If the earth's axis of rotation were perpendicular to the plane of its orbit there would be no seasonal changes at all. An increase of its inclination, on the other hand, would cause hotter summers and colder winters. Because such increases actually occur, as a long-range effect of the gravitational pull of the planets, we should expect certain differences in the mean summer and winter temperatures during the various geological epochs.

Yet how would these changes cause the formation or disappearance of ice sheets? Colder winters are balanced by hotter summers, and warm winters by cool summers, so the earth's total annual income of solar heat remains on the average the same in all periods. The fact is that ice sheets form during periods of comparatively warm winters. The explanation of this paradox is simple. Snow falls in mild winters as well as in cold ones. So long as the temperature falls below the freezing point of water, it does not matter how cold the winter gets; the moisture in the air will be precipitated as snow in any case. But the summer temperature makes a big difference. A cool summer melts less of the winter's ice than a hot one does. Hence in an epoch of warm winters and cool summers the glaciers gradually grow; each year more and more of the winter's ice survives the summer and piles the ice sheet higher in the succeeding season. And under the increasing weight of snow and ice, the glaciers creep down from their highland sources.

We have seen that there are three factors responsible for cool summers: 1) precession; 2) decreasing eccentricity of the earth's orbit; 3) straightening of the earth's axis under the gravitational pull of other planets. When all three factors act in the same direction we would expect exceptionally cool summers and the exceptionally fast growth and advance of ice sheets.

PUTTING together all the existing calculations of the long-range changes in the earth's motion during the past 500,000 years, a Yugoslav geophysicist named Milankovitch, constructed a curve showing the amount of solar heat which was radiated during the summer months upon the Northern and Southern Hemispheres in the course of each geological epoch. In the accompanying chart, this curve for the Northern Hemisphere, calculated entirely on the basis of astronomical data, is compared with another curve that represents the successive advances of the glacial ice sheets, as they have been estimated by geological studies. The agreement between both curves is striking, and proves beyond any doubt that the glaciations of the past were due to the variations in the earth's orbit caused by the disturbing gravitational pull of other planets.

If this is true, we can predict the major future changes in the earth's climate! All

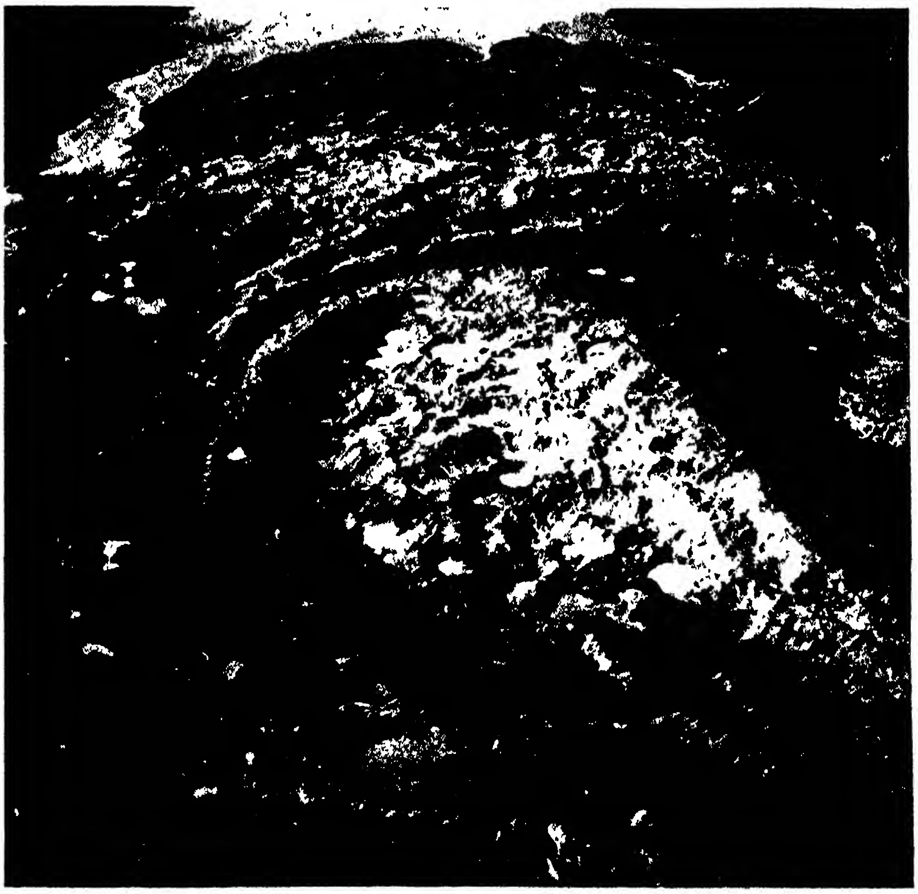
one has to do is to use the data for the future changes of the earth's orbit, and to calculate the heat balance of our globe for the centuries to come. The basis for such a long-range weather forecast (which is much more reliable than the predictions of rain or sunshine for tomorrow published in our newspapers) is given by the right-hand side of the curve shown in the same chart. It tells us first of all that the climate of the earth is gradually getting warmer, and that this long-range heat wave will reach its maximum stage about 20,000 years from now. No trace of ice will then be left in the northern regions and the shores of Baffin Bay will be covered with palm groves, their leaves rustling softly under the caressing breath of the northern winds. The naked lands of the North, where at present adventurous hunters set their traps for lynx and silver fox, will be covered with thick tropical vegetation and populated by animals which now can be found only in equatorial forests.

Twenty thousand years is a long time from the point of view of our individual lives, but it is a moment in geologic history, and it is not even long in terms of human history. It must be remembered that these changes of climate are taking place gradually even now. If the climate favorable to the growth of palm trees is to move from Florida to the Labrador Peninsula in the course of the next 20,000 years, the "palm line" must be moving northward at the rate of about a quarter of a mile per year. Four centuries ago, when Columbus discovered America, the northern boundary of tropical vegetation must have been about 100 miles farther south than it is at present. Due to the gradual warming of our globe, Toronto will have a climate like that of present-day New York City in 5.000 A.D., like that of New Orleans in 10,000 A.D., and like that of Miami in the year 15.000. Then, as the centuries pass, the heat wave will gradually wane and give way to a new advance of ice. By about the year 50.000 A.D., large masses of ice will start creeping down from the northern highlands to form a new ice sheet that will erase the cities of Canada and the northern U.S. from the face of the earth. The European cities of London, Stockholm and Leningrad will also fall victim to ice sheets descending from the Scandinavian mountain ranges. This next glaciation will be followed later by another warm wave, and still another more extensive glaciation around 90,000 A.D.

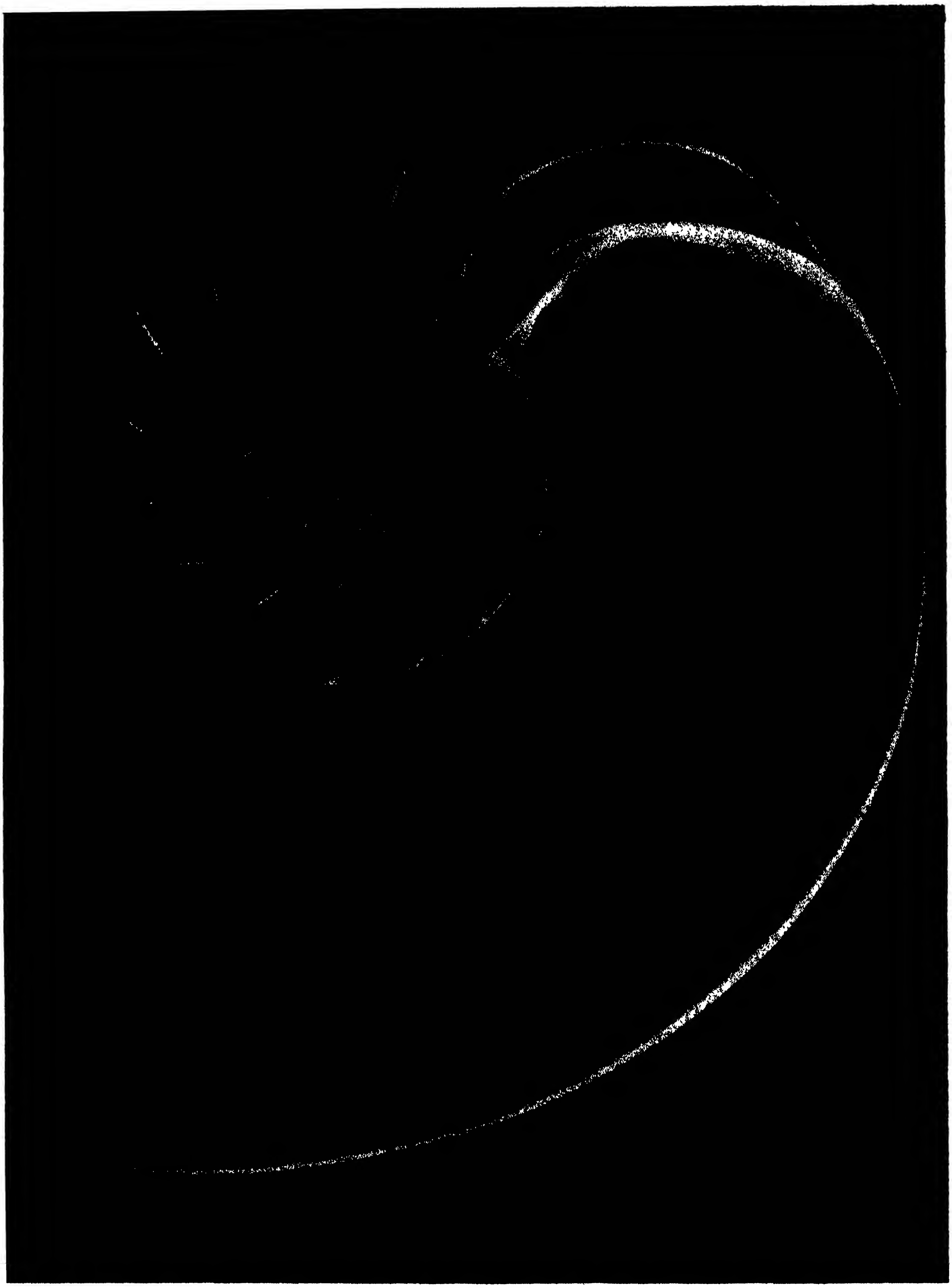
But with more immediate destructive forces to think about, perhaps this is looking too far ahead.

George Gamow, professor of physics at George Washington University, is author of Birth and Death of the Sun *and other popular scientific books.*

RETREATING GLACIER leaves distinctive marks on the land. At top is edge of Woodworth Glacier in Alaska. At right are deep striations. At left are alluvial fan and bed of stream that flowed from earlier glacier front.



PROFUSION OF LAKES is left in the wake of the melting Woodworth Glacier. The speed of the glacier's retreat may be calculated from characteristic layers of sediment deposited in the lakes during the winter and summer.



X-RAY PHOTOGRAPH of the shell of the pearly nautilus shows that it is right-handed, *i.e.*, the shell spirals in a clockwise direction. Most snail shells are right-handed, although a few spiral to the left. This shell, photographed by the General Electric X-Ray Corporation, is from collection of Chicago Museum of Natural History.

RIGHT HAND, LEFT HAND

Considering the phenomenon in man, zoologists have examined such things as the spiral shell of the snail and the flounder's traveling eye

by Lorus J. and Margery J. Milne

ARE YOU right-handed or left-handed? Are you sure? Which shoelace do you tie first? Which foot is the initial recipient of soap in a bath? Which eye do you prefer to use for peering into a telescope or microscope? Only a very small proportion of people are mixed in their replies to such a questionnaire. You may think you use both hands for controlling an automobile, but which driving glove wears out first? Unevenness of wear led thrifty farmers to invent the "work mitt" with a thumb on each side. Then the mitts can be worn equally well on either hand and wear can be equalized by alternating them.

Only occasionally have serious researchers looked into these preferences for right over left. Somehow the subject seems trivial to most of them. Only efficiency experts become greatly exercised over the arrangement of tools for the most productive use of hands and feet. Their "time and motion" studies frequently stress the need of adapting working space to the mental habits of the human being in an assembly line. Psychological literature is filled with frustrations of people whose native preference was for the left hand, yet who were forced by circumstance to employ their right. There can be no doubt of the constant pressure to change under which left-handed children mature. That more than seven in every hundred nonetheless persist in becoming "southpaws" is a clear demonstration of the strength of their inner urge.

Even the first step a baby takes in life is important. Uncertain though it is, that initial stride is predetermined to begin with a certain foot. The chances are better than nine to one that the right foot starts it off. Soon this choice becomes a habit. Upstairs, downstairs or on the level, the more adventuresome toes regularly take the lead. Some day a tough sergeant may reverse that pattern, so that marching begins with the left foot. But army drill manuals notwithstanding, the human population shows an early preference in such matters. The military "hup, two, three, four," with "hup" starting the left foot, is for most people the hard way of doing it.

Human beings are by no means the only possessors of this preference. Training a dog to "shake hands" with either forepaw is likely to make the animal a neurotic. incapable of following through with any tricks at all. The hunting dog that points to game by raising a folded foreleg and "freezing" is not told which foot to raise. Invariably the same one is used. Two dogs may differ. but neither varies his own procedure. Parrots may be a bit more versatile. Yet of 20 in the National Zoological Park. Washington, D. C., almost three quarters were usually left-handed, and three of them were invariably so. Elephants are set in their ways too, and the difference determines which of the two tusks will yield the greater weight of ivory. In a right-tusked elephant, the left is the unused side that brings the higher price. The right tusk is worn down by the animal in digging for food among roots and shrubbery. Never do the two monstrous pieces of ivory weigh even approximately the same.

Whether this right- and left-handedness in man and elephants stems from any real difference in the mental make-up is still an unproved point. No anatomical basis for it at birth has been found, although statistical studies give strong indication that such a basis may exist. Nor do human beings show the degree of uniformity that is known in some insects. By comparison with man, all katydids might be called left-handed, all crickets right-handed. Each kind has perfect uniformity in the way it holds its wings at rest. This uniformity is based upon a very careful positioning of the wings that takes place when the insects molt for the final time and acquire their flying appendages. Before their wings have dried and hardened, cricket and katydid each folds the bases together precisely as they belong. Any error in this detail is likely to leave the nonconformist without progeny. The male of each kind attracts a member of the opposite sex by scratching one wing against the other to produce the sounds we all know. An erring insect would be mute—and mateless—for only when the wings are overlapped in the correct way can a small tooth on the inside of one wing rub over a series of ridges on the other. Right wing over left is the cricket system; left over right is the katydid.

Connoisseurs of seafood know that a lobster's claws are not alike in size or shape. Usually the left is the more massive crusher, with far greater power and meat. This rule holds also for many crabs. the lobster's short-tailed relatives. In the males of fiddler crabs, which swarm over mudflats at low tide to forage for refuse, the larger claw is many times the size of the opposite member. The name fiddler comes from a supposed similarity of the left and right pincers to a violin and bow, respectively. Yet occasionally one of these crustaceans is found with the right claw the larger—a mirror image of the usual situation. This comes about in a strange way: If a lobster or crab loses its larger nipper in an accident, the creature produces a new one by regeneration; it appears after the skin is molted. When this occurs in the male fiddler crab, the original smaller claw (the right) becomes a big one. It is now the violin, and the new left claw has the form of the lesser member (the bow). A left-handed crab has become right-handed, and it gets along perfectly with the new arrangement. It can switch back and forth at each molt, and never become seriously mixed in managing its nippers. Yet the basic left-handedness of fiddler crabs is proved by the fact that if both of the male's pincers are lost at one time, and the two new ones are formed ready for the next molt, the crustacean brings forth its fresh armament in the pattern of its forebears. The left is the larger of the two, and has the thicker base and little teeth for holding food or injuring enemies.

ALMOST all snails are either right- or left-handed, and show this in the architecture of their shells. Most are right-handed, or "dextral." If you inspect the coiled whorl of such a snail from its pointed end, you will see that the chamber spirals to the right, clockwise. The common water snail, however, is almost without exception left-handed. A few seemingly ambidextrous kinds are known which may construct the shell in either direction.

For reasons unknown, the direction of coiling of a snail shell appears to be more fundamental than the choice of foot for a first step by a human infant. Scientists have gone to great trouble to explore the source of difference between a clockwise and a counterclockwise shell. For many years it was believed that the direction was determined during the very early divisions of the snail egg. The original single cell divides to become two, hud-

dled side by side. Each of these divides, and the resulting cluster of four is arranged like a quartet of miniature billiard balls tightly grouped in the middle of the table. When these four divide again, the direction in which the shell (still far in the future) will coil is settled then and there. For this third cleavage produces a second tier of four somewhat smaller cells, which are not balanced squarely on top of the basic four but are twisted into the valleys between them. Thus the spiral begins. If the twist is in the clockwise direction, the snail-to-be will have a right-handed body and covering shell.

What decides the direction of this spiral cleavage? A snail packages in its egg not only materials but detailed directions for construction of one complete and active offspring. Is handedness determined by the positions in the egg of the various substances of which it is composed? To test this hypothesis, snail eggs were whirled at high speed in a centrifuge. Forces many times the strength of gravity completely rearranged the stuff that snails are made of. If the eggs developed after this rough treatment, and if handedness depended on the position of egg substances, by the laws of chance half of the snails that matured should spiral clockwise and half counterclockwise. But every one of the centrifuged eggs became, like its parents, a right-handed (clockwise) snail. Over and over the experiment was tried. In a matter of seconds after the machine stopped, all the substances displaced in the centrifuge hurried back to their appointed places, so that subsequent divisions of the egg apportioned the ingredients correctly. Somehow, if life was possible at all, the mollusks recovered their directions. The matter of handedness is now recognized to be implanted by the snail mother when she first matures the egg. It is a feature of the living matter of the egg itself, and not a mere question of arrangement of food supplies stored in it. Handedness in other animals may be equally fundamental.

Consider the unbalanced flounder, sole and halibut, all of which have flat bodies and curiously distorted heads. They lie on the ocean bottom and wait for food to move near their grotesquely misshapen mouths. These fish start out as symmetrical as a sardine. They swim through the early weeks of life as gracefully as any minnow. Then they begin to haunt the bottom, and to lie over on one side as no healthy fish does ordinarily. This procedure brings one eye dangerously near the mud, where it is not only useless but actually risks destruction. The flounder and its relatives solve the problem by gradually shifting that eye to the side which is uppermost. The whole organ migrates over the fish's back and reaches a position of usefulness and security again. Optic nerves furnish added length to make this possible, and carry messages from the migrated eye around to the undersurface of the brain to enter in the proper place.

MIGRATING EYE of the flounder illustrates right-handedness. Most flounders lie on the bottom with left side down. Eye slowly travels to the right.

At the same time the mouth twists so that it can bite almost vertically. Now the flatfish is ready to live its new, lazy existence, practically a part of the bottom upon which it rests.

As interesting as this metamorphosis is the fact that these fishes also show a clear recognition of right and left. Almost invariably the flatfishes lie on their left sides, with only the right surface exposed. The fins, which in other fishes extend along the midline above and below, fringe the flatfish as it spreads itself on the sand. The right surface becomes its "back." It comes to bear two eyes, both nostrils, and most of the mouth. In spite of this altered attitude of the animal, the brain remains symmetrical.

RULES usually have an exception or two. Along the Pacific coast is an ambidextrous flounder. In the waters of California it follows the ordinary right-handed tradition. Farther north, an occasional eccentric turns its left side uppermost. Still farther north, in British Columbia, half of the flounder population lies on its right side and half on its left. Near Alaskan waters the fish is found almost entirely in the left-handed position. Scientists have interested themselves in this unusual phenomenon, but their chief discoveries have been anatomical details. Flounders ought to be right-handed, if they knew what was good for them. When they lie down on the wrong side and expose their left flanks, the eye migrates to the upper surface normally enough, but the nostrils become hopelessly twisted. The nerves connecting them to the brain do not follow the 30-degree rotation that is required for the shift. They proceed to become completely entangled, and it is doubtful that a left-handed flounder has full use of its sense organs.

Even the lowly oyster displays handedness. The mollusk begins life as symmetrical as any clam. But when the "spat" stage is reached, the little oyster fastens its one shell to a rock or other solid object and begins to grow more and more unequal. Its forebears long ago settled the problem of which side was which. Again it is the left that goes under, and forms the ever-broadening valve that supports the soft body. When next you meet an oyster on the half shell, you need be in no doubt about which half it is. Ten chances to none it is a right. The opposite was the heavier of the two shells, and remained in the kitchen.

These nonhuman examples are interesting and informative, but man would like to think that his own preponderant right-handedness has a rational basis. Some have argued that the preference

LOBSTERS are left-handed. As anyone who has eaten a lobster knows, one claw is more massive than the other. In most lobsters it is the left claw.

originated from the way a baby is held by its mother. This theory does not hold water. If a right-handed mother kept her favored hand free by carrying her infant on the left, the baby's right arm would encircle her neck while its left would be free to snatch at things. Thus it might be expected to become left-handed. If the baby were a girl, she in turn might eventually carry an infant—but place it on the right shoulder and reverse the picture. It doesn't work out that way.

ANOTHER argument is more ingenious. The heart is to the left side of the midline of the human trunk, and warriors in shield-carrying days found that a buckler carried on the left arm protected the vital organ more completely. The right was then free for wielding sword or spear. Right-handedness thus had an important relationship to fighting for survival. But not all men were warriors, and the women could scratch or pull each other's hair equally well with right or left. Imitation is not a good enough theory to explain the situation. Besides, the heart is not as far to the left as many people believe. Every year many would-be suicides survive their own stabbings because the heart is nearer the midline than they suppose. And knowledge of anatomy in shield-and-spear days was even more vague.

Can the preference be due to some structural feature that has nothing to do with such conscious motives? Possibly so. The unequal distribution of heart, stomach and other viscera makes the right half of an adult some 15 ounces heavier than the left. The center of gravity is displaced, and when the lungs fill, the liver shifts farther to the right, making the situation even more uneven. Carrying a light weight (a pound or so) on the left arm tends to improve weight distribution in the body, and better the balance for walking or running. Obviously the right hand is free.

The human right lung is three-lobed, the left only two-lobed. In the deep breathing that accompanies violent exercise, the change in dimensions of the right lung is far more pronounced than that of the left. Does a load carried against the chest interfere less on the left arm than on the right? This is a good question. The suggestion becomes even more interesting when one notes that a few cases of left-handedness have been shown to accompany transposed viscera—that rare situation in which the heart is on the right, the appendix on the left.

Others maintain that handedness is determined by a difference in the amount of blood reaching the two halves of the brain. But none of these arguments explains the four to eight per cent of the normal population who are completely left-handed, or the 10 to 15 per cent who are reasonably ambidextrous, or why there is a much higher percentage (16 to 30 per cent) of left-handedness among inmates of institutions for the feeble-minded and psychopathic.

A number of tests have been devised to learn the consistency of preference for right or left. They classify an individual into one of four groups: pure left-handed (LLL), pure right-handed (RRR), or mixed, with a strong tendency toward the left (LLR) or the right (LRR). For example, which is your spade foot? Neither, most gardeners will say, for when one gets tired the other is used. But many people show definite awkwardness in using the "wrong" foot on a shovel. Which eye is the dominant one? Hold a pencil at arm's length with both eyes open and place the pencil between some far object and yourself. Shut the right eye. If the pencil is still in line with the test object, you are left-eyed. Are you left-handed too? Half of the people who are left-handed are also left-eyed, but only 30 per cent of right-handed people prefer their left eye. Which eye do you close when you wink? Again there is some uniformity, but the answer is surprising. Most right-eyed people (if they do not wink easily with either eye) close the left. The dominant eye stays open.

Clasp your hands, interlacing the fingers. One thumb tops the ten, but which is it? Try the other arrangement; it isn't nearly as restful. Then fold your arms across the chest. One hand comes over the upper arm, while the other is tucked down out of sight. But what do these tests mean? The psychologists argue about them, and miles of statistics have been multiplied out to prove something. They show that more women than men are right-thumbed. Often they indicate that inheritance may play a large part in determining thumbedness. But there is no correlation with handedness when large enough numbers of people are tested.

The tests show that some of the things we do with feet or hands are clearly dependent on an inborn difference. Thus the right-handed stenographer (RRR) makes more mistakes with the left half of the keyboard. But other things, such as thumbedness, are not a part of the same picture. No ultimately consistent pattern of handedness can be discerned. And when it comes to giving an explanation of why one person is right-handed and another left-handed, or why katydids, crabs and parrots favor one side and crickets, snails, flounders and oysters favor the other, we must wait for further investigation of this fascinating problem.

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THE CHEMISTRY OF SILICONES

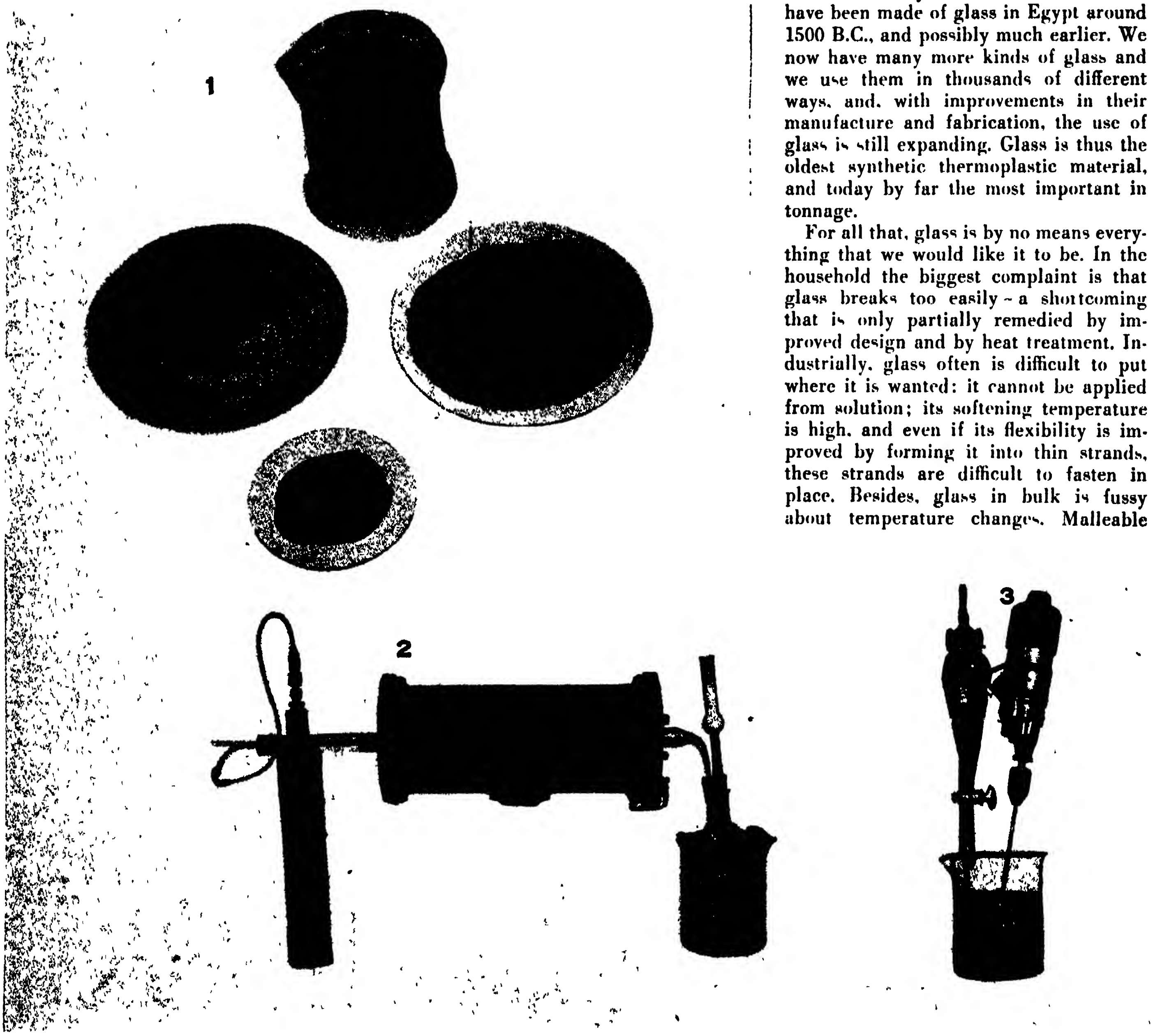
The artificial compounds that have created many new products are the offspring of the marriage of organic to inorganic chemistry

by Eugene G. Rochow

THE word silicone is easy to say, and it obviously has something to do with the element silicon. Its chemistry, however, involving such eye-stopping terms as dimethylpolymethylenedioxysilane, has seldom been explained outside of technical journals. Fortunately, the silicones have a legitimate chemical kinship to ordinary glass and to the more common plastics, so it is not too difficult for the layman to get some idea of what silicones are all about.

Glass is an exceedingly useful and versatile material. While we might like to think of it as a product of modern science, the use of glass in one form or another actually goes back at least to the beginning of recorded history. Pliny states that man-made glass first resulted from the fusion of sand and soda in an open fire built by sailors shipwrecked in the Mediterranean, but objects of art are known to have been made of glass in Egypt around 1500 B.C., and possibly much earlier. We now have many more kinds of glass and we use them in thousands of different ways, and, with improvements in their manufacture and fabrication, the use of glass is still expanding. Glass is thus the oldest synthetic thermoplastic material, and today by far the most important in tonnage.

For all that, glass is by no means everything that we would like it to be. In the household the biggest complaint is that glass breaks too easily – a shortcoming that is only partially remedied by improved design and by heat treatment. Industrially, glass often is difficult to put where it is wanted: it cannot be applied from solution; its softening temperature is high, and even if its flexibility is improved by forming it into thin strands, these strands are difficult to fasten in place. Besides, glass in bulk is fussy about temperature changes. Malleable



STEPS IN THE SYNTHESIS of a silicone oil are shown in laboratory demonstration. At upper left (1), reading clockwise, are four substances: methyl chloride, pulverized silicon, powdered copper and lump silicon. The methyl chloride is passed through a heated tube containing silicon and the catalytic copper powder,

glass does not exist except in the old myth about the artisan who presented his king with a glass goblet hammered free of dents and promptly was liquidated to preserve the secret. All these reasons explain why so many plastics have been developed to take over some of the functions of glass.

Some plastics are as transparent as glass, some are exceptionally strong and tough, some are flexible and resilient, and all can be fabricated at moderate temperatures. The electrical industry has plastic insulating varnishes, the paint and enamel industry has soluble and oil-modified resins, and the molding industry has an extensive range of well-known colored and transparent plastics.

UNFORTUNATELY the glass-clear plastics scratch easily and soften or distort even at the relatively low temperatures of hot water. So while their transparency is a useful property, they do not by any means displace glass in most of its applications. Until recently there remained a considerable gap between glass and the plastics, both in composition and in range of utility. Now come the silicones, which are relatives of glass and have intermediate properties and usefulness. Silicones still are far from malleable glass, but they are an interesting compromise.

The silicones are polymers (from the Greek *polys*, many, and *meros*, part), meaning that they are large molecules made by combining simpler compounds. Their chemical significance is that they represent a marriage of organic and inorganic materials. Synthetic plastics generally are organic and therefore carbonaceous, while glass is inorganic and siliceous; most chemists believed that never the twain would meet. In the silicones they not only meet but combine in a particularly useful manner.

The story of how silicone research began in the U. S. is an interesting one. Here and there a few people especially fitted by training and experience had pondered a possible mingling of the ceramic and plastic arts. E. C. Sullivan, vice president and director of research at the Corning Glass Works, hired James F. Hyde, a young chemist fresh from Illinois and Harvard, to look into the possible middle ground between the various glass compositions and the newer glasslike organic plastics. At about the same time, Winton Patnode of the General Electric Company's laboratories at Pittsfield and Schenectady began to think about the possibility of extending the field of synthetic polyester resins by creating semi-inorganic compositions from silicon and organic alcohols and amines. He hoped that such hybrid substances might withstand the heat developed in electrical equipment better than the plastics that were then available. Up to that point only mica, porcelain and glass could be used in motors or other equipment which might become too hot for cellulose and other organic insulations.

Patnode began by preparing combinations of silicon tetrachloride with ethylene diamine and glycols. He obtained sticky masses which solidified rapidly and withstood the heat satisfactorily, but were affected too much by water. This was in the early stages of the depression, and there were many pressing problems to distract Patnode and Hyde from their experiments, but they managed to keep their independent investigations going. They were known to each other, and at one time W. R. Morrow, then manager of the Fiberglas Division of Corning, suggested that Corning and General Electric join forces in the hope of developing a synthetic substance which would be a suitable binder for Fiberglas and stimulate its use in electrical machinery. Nothing came of his suggestion, and for the most part the two investigations traveled separate paths and produced quite different materials. Nonetheless, since the ultimate aims were similar, it was natural that they should reach some common ground in the general type of product they evolved. That common ground lies in the substances we now call silicones.

THE word silicone was coined 36 years ago by Professor F. S. Kipping of University College, Nottingham, England, to describe substances of the empirical composition R_2SiO, where R represents any organic group bonded directly to silicon (Si), which in turn is linked to oxygen (O). These substances are analogous to a general class of organic compounds, the ketones, all of which have the empirical composition R_2CO. A distinctive badge of the ketones, however, is the carbonyl group (C=O), in which carbon is doubly bonded to oxygen. No comparable situation is known for silicon. In all the compounds of silicon and oxygen that have been examined, the silicon atom is singly bonded to oxygen, and each oxygen atom therefore is bonded to two different silicon atoms.

This state of affairs will be seen at once to lead to a polymeric body, for as soon as there is at least one oxygen for each silicon, there must result a chain of alternate silicon and oxygen atoms, according to the scheme shown in the diagram which appears at the top of page 53. This is called a siloxane chain, and it occurs in quartz and the silicate minerals as well as in silicones.

If there are more oxygen than silicon atoms, the only way that the extra oxygens can take up their accustomed places is by joining neighboring siloxane chains, as shown at the bottom of page 53. This still further increases the polymeric com-

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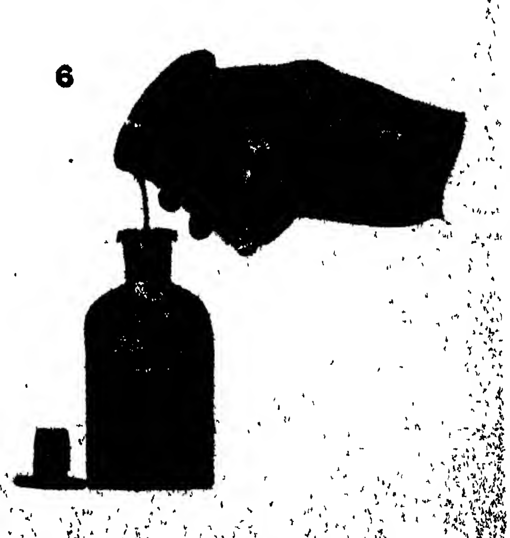


producing a mixture of methylchlorosilanes (2). After dimethyl dichlorosilane has been separated by distillation (*not shown*), it is stirred with ice and water (3).

The product is then shaken with sulfuric acid (4). The sulfuric acid is later separated (5), leaving layer of silicone oil in funnel to be poured into container (6).

plexity and the molecular weight of the substance. With sufficient joining or cross-linking of the chains, all degrees of molecular size become possible. The organic groups are attached to silicon atoms in the chain wherever there is an unoccupied valence bond.

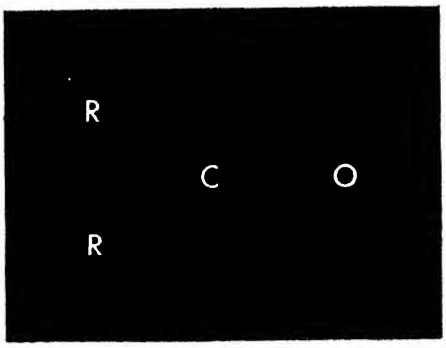
Silicones therefore are organosiloxanes which are polymeric by virtue of the atomic behavior of silicon. Naturally the organic groups in the compound influence the character of the polymer and the way it behaves. Methyl groups (CH_3) are the most useful because they introduce a minimum of carbon and hydrogen into the siloxane structure and so take fullest advantage of its properties. Phenyl groups (C_6H_5) are the next most valuable; they, too, resist oxidation and stand high temperatures, and in addition impart a sticky or resinous character to the silicone polymers.

Many silicones have been made with other kinds of organic groups attached to the silicon atoms. For the purposes we are considering, it is found that the larger the straight or branched-chain organic group attached to silicon, the more easily it is split off by oxidation. The combination of various properties makes methyl silicone of particular interest and value, although we should by no means forget the other compositions.

THANKS to 80 years of accumulated work on the synthesis of organosilicon compounds, there are several well-developed methods for joining the organic groups to the silicon atoms. As starting material the methods may use either elementary silicon itself or silicon tetrachloride ($SiCl_4$), a volatile reactive liquid. We shall consider only the two processes that are of current industrial importance.

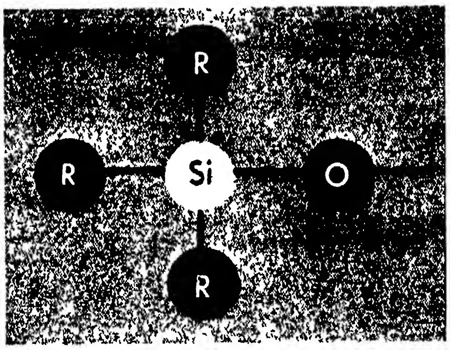
In the first, methyl chloride acts upon metallic magnesium suspended in dry ether to produce methylmagnesium chloride, long known in the organic laboratory as a useful reagent in syntheses. This is then allowed to react with silicon tetrachloride by adding it slowly to a stirring solution of the latter in ether. The principal product is dimethyldichlorosilane, $(CH_3)_2SiCl_2$, in which two methyl groups have been substituted for two of the chlorine atoms in $SiCl_4$. Actually there is obtained a complex mixture of methyl-substituted silicon chlorides in which dimethyldichlorosilane predominates, so the pure compounds must be separated by distillation.

In the second method, vaporized methyl chloride reacts directly with powdered elementary silicon in a heated tube, using powdered copper with the silicon as a catalyst to hasten the reaction at moderate temperatures. The product of this reaction again is a mixture of methyl-substituted silicon chlorides or methylchlorosilanes, although this time without the ether. By either method a rather difficult distillation procedure is necessary to separate the individual methylchlorosilanes because their boiling points are so close together, but the separation can be achieved. The principal compounds that are required in a pure state are $(CH_3)_2SiCl_2$, CH_3SiCl_3 and $(CH_3)_3SiCl$. Of course, similar methods of synthesis may be used to obtain other organochlorosilanes.



KETONES are class of organic compounds similar to silicones. Carbon (C) has double bond with oxygen (O).

Having isolated the methylchlorosilanes as intermediates, we are ready to start making silicone polymers. To make methyl silicone resins, we may take a mixture of CH_3SiCl_3 and $(CH_3)_2SiCl_2$ and hydrolyze it by stirring it with a mixture of water, ice and some suitable organic solvent. The chlorine atoms will leave the central silicon atom to combine with hydrogen from the water, leaving hydroxyl (OH) groups on the silicon in their place. These hydroxy compounds are stable only if large organic groups on the silicon atoms block access to them. Since only the simple methyl groups are present in our example, the hydroxyl groups readily approach one another and interact to



SILICON (Si) forms only single bond with oxygen, leaving the latter free to combine with another silicon atom.

produce water and form siloxane chains of the type discussed earlier. This condensation takes place simultaneously with the hydrolysis, and the condensed methyl siloxane polymer (silicon resin) remains dissolved in the organic solvent while hydrochloric acid enters the water layer. The solvent layer is separated, washed free of acid, and then is adjusted in concentration. Methyl phenyl silicone resins may be made in a similar way by cohydrolyzing methyl and phenyl chlorosilanes.

The silicone resins made in this manner are sticky, colorless substances which harden to insoluble horny masses upon further heating. The hardened or cured resin may be used at temperatures as high as 200 degrees C. (and even 300 degrees C. for limited periods) without decomposition or oxidation. Methyl phenyl silicone is used extensively as an insulation and as an adhesive for mica in the electrical industry, and more recently in protective coatings having remarkable resistance to aging and to chemical attack. Similar silicone resins have become the sought-for binders for Fiberglas, and the combination is widely used as insulation for motors, transformers and control equipment.

One kind of silicone resin is baked on bread pans to form a hard shiny "glaze" that allows the bread to be removed easily without resorting to the old-fashioned greasing. One coating of the glaze lasts for many bakings, and a smooth, clean loaf emerges each time.

The methyl silicone resins derive their resinous character from their deficiency of methyl groups: because there are fewer than two methyl groups per silicon atom, the compound has extra oxygen atoms which, as we have seen, are responsible for the cross-linking and curing of the resins. When pure dimethyl silicone first was made, chemists seeking resins found it disappointing because it was oily. However, they soon found that the straight-chain molecules of the oily substance could be made to grow larger, and that the "macromolecules" so produced were decidedly elastic. When the rubbery gum obtained by growth of the oil molecules was milled with filler and put through a process chemically akin to the vulcanization of rubber, there was obtained a silicone "rubber" which seemed for all the world like natural Hevea rubber, except that it did not liquefy and decompose to a malodorous mass when it was strongly heated.

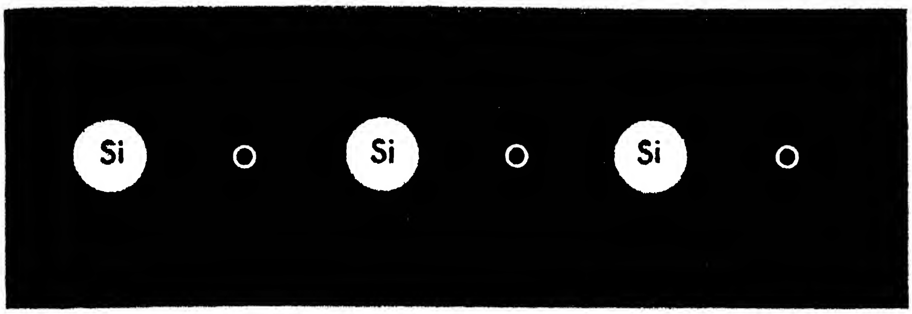
This new silicone rubber stood high temperatures as well as its resinous cousins, and could be used for flexible gaskets and protective coverings far above the accustomed temperature range for organic rubbers. Aircraft motor and supercharger gaskets soon were in service, and proved their worth. Many different silicone rubber compositions, all with different properties, have since been made and have found specialized application. An indifference toward hot lubricating oil, plus good electrical insulating properties, have helped these new elastomers find industrial acceptance. Fortunately silicone rubber tolerates very low as well as very high temperatures without losing its rubbery qualities. It would do nicely for an inner

tube literally capable of going through hell and high water, but some improvements are needed before a good silicone tire casing becomes possible.

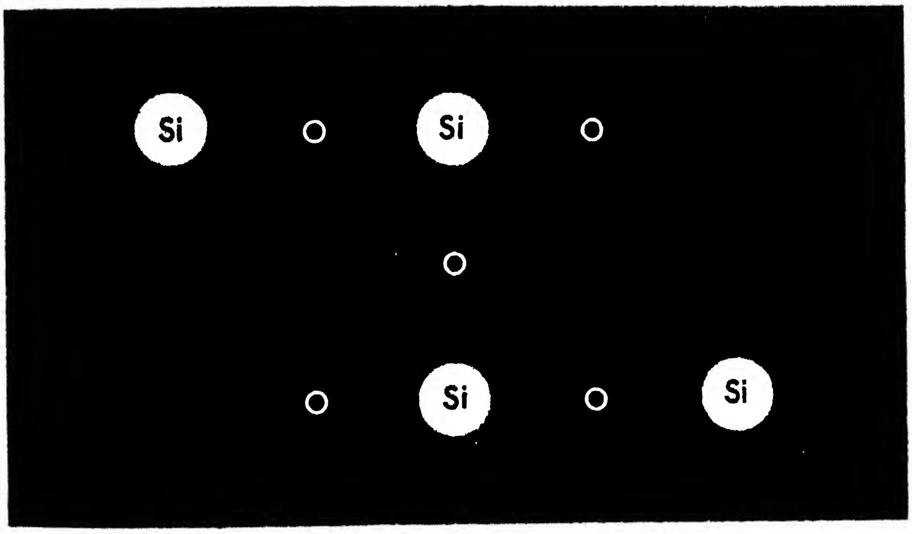
There was no particular reason why the oily dimethylsilicone polymers had to stand idle, and "silicone oil" soon became interesting as a lubricant and as a dielectric fluid. Something had to be done, however, to keep the molecules at a constant size, for if further intermolecular condensation took place in use, the oil would thicken and eventually would gel. A method of attaching nonreactive trimethylsilyl groups was developed, and "tailor-made" silicone oils of a fixed molecular size and viscosity resulted.

The most surprising property of the new oils was found to be their small change of viscosity with varying temperature (indeed, all the properties change slowly with temperature). This means that silicone oils do not thicken as much when cold, nor thin out as much when hot, as do the petroleum oils. Some immediate applications to instrument lubrication and to aircraft hydraulic systems became possible, and now silicone oil serves even as prosaic a purpose as a heating bath for the laboratory. Some special and quite unexpected uses are interesting: a few parts per million of silicone oil in the lubricating oil of large Diesel motors stops the foaming of the oil, and a thin film of silicone oil on the metal surface of a tire mold prevents the rubber from sticking to it. Silicone oil does not swell natural rubber; conversely "natural" oil does not ruin silicone rubber.

The small intermolecular attraction in methyl silicone systems, which is tied up with the small thermal change of viscosity in silicone oil and the comparatively low tensile strength of silicone rubber, has been a subject of interest and speculation among chemists for some time. Walter L. Roth of the General Electric Research Laboratory, who has long been interested in the structure of silicones, says that his evidence from X-ray diffraction indicates that dimethylsilyl groups have an unusually free rotation about the siloxane bond —as though the bond were a ball-and-socket joint. This motion causes the dimethylsilyl groups to sweep out a large space and occupy a large volume, thus preventing the close approach of neighboring molecules and hindering the attractive forces that come into play at close range. The freedom of motion is considered to be due to the rather high ionic nature of the siloxane bond, which makes it less directional and less rigid than the single covalent bond between carbon atoms.



CHARACTERISTIC of silicones, based on the property illustrated at bottom of the opposite page, is tendency of silicon and oxygen atoms to form long chains. Organic groups may then be attached to the silicon atoms.



MORE COMPLEX CHAIN of silicon and oxygen results when there is a relative abundance of oxygen present. Oxygen atom then acts as a bridge between two chains, permitting the synthesis of more elaborate structures.

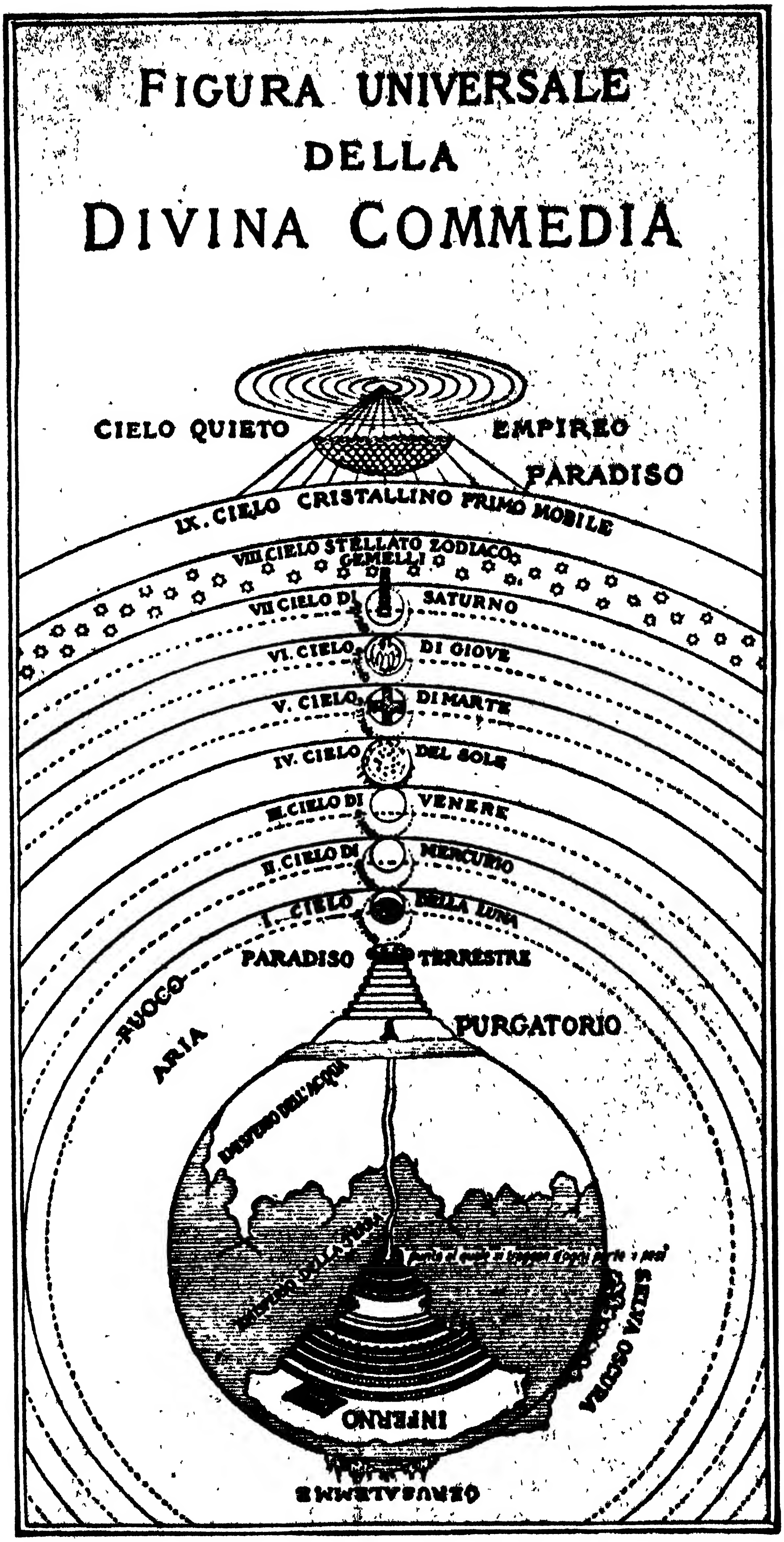
LIKE many planned programs of research, those described here did not produce the materials originally sought. Neither a clear moldable plastic nor a malleable glass has been obtained—nothing that was originally desired, except a binder for Fiberglas. Like many "unplanned" investigations, those here described did turn up many interesting facts and materials never envisioned when the first experiments were started. Perhaps the best example lies in the strongly adherent water-repellent films found to be deposited on many surfaces by reaction of the vapor of methylchlorosilanes or by any of a number of liquid organosiloxane preparations. The invisible organosiloxane film, only a few hundred molecules thick, sheds water droplets like the proverbial duck's back. It suggests a wide field of uses in waterproofing paper, textiles and building materials.

So the silicones, long known only in textbooks, now have spawned a new industry of unexpected variety and promise. Today there are two large plants busily making silicone materials in this country. It is exclusively an American industry. There was no silicone technology in Germany before or during the war, and in England commercial exploitation is just starting, despite the fact that Professor Kipping's classical researches were carried out there for more than 40 years before.

There is no shortage of raw materials in sight for silicone manufacture. The elements silicon and oxygen are the two most abundant on the earth's crust, constituting together about 76 per cent of the world as we know it (by contrast, iron constitutes 4.7 per cent and carbon 0.09 per cent). The organic groups may be derived from coal or petroleum or wood. The particular organic compounds required for making silicones are rather simple as organic molecules go, and are already in large production for other uses. The reactions that serve to unite silicon with the organic groups are not particularly complicated or difficult, even though they are new to industry.

This favorable raw material situation and the unusual properties of silicone polymers make it probable that silicones are here to stay. Nor need we add "for better or worse," as so often is necessary, for so far the uses of silicones have been decidedly beneficial.

Eugene G. Rochow is associate professor of chemistry at Harvard University and author of the book An Introduction to the Chemistry of Silicones.



DANTE'S UNIVERSE, here pictured in a drawing based on the *Divine Comedy*, located not only Hell, Purgatory and Paradise but orbits of planets. An enduring work of literature, *Comedy* summarized 14th-century science.

by I. Bernard Cohen

WITHIN recent months a number of books dealing with various aspects of the history of science have been published. The most important, and the first to be discussed in this article, is the long-awaited third installment of George Sarton's *Introduction to the History of Science* (Williams & Wilkins Company, Baltimore). Subtitled "Science and Learning in the Fourteenth Century," this significant work surveys, for the period under consideration, every aspect of man's thinking that bears in any way on science. It is an admirable example of the special field of scholarship in which its Harvard author was a pioneer.

George Sarton's lifework has been fitted into a consistent and clear pattern that he set about 40 years ago when, as a young Belgian scientist trained in mathematics and chemistry, he recognized that the history of science was worthy of study as an independent discipline. Today it seems obvious that the history of science is as important as that of philosophy, religion, art, literature or music. Indeed, science is the only aspect of man's intellectual endeavor in which we can record and measure progress.

The development of science, which has been termed by President James B. Conant of Harvard "accumulative knowledge," may be contrasted with fields of "non-accumulative knowledge" such as literature or painting by means of a simple test. Let us imagine that such men as Michelangelo and Dante in art and literature and Galileo and Vesalius in science were brought back to life today. Would they consider that progress had been made in their respective fields? Dante and Michelangelo would not necessarily acknowledge the poetry and painting of our day to be superior to their own. But Galileo and Vesalius could not help agreeing that enormous progress had been made in physics and anatomy.

When George Sarton began his work in the history of science, the study of the history of science had not yet been made popular by such great men as William Osler, William H. Welch and Harvey Cushing. Few courses were offered in the history of science, and there was little if any opportunity for graduate study and

BOOKS

The history of science as a record of the march of human thought: a review of George Sarton's monumental work and some other recent histories

training in the field. The standards of scholarship were far below those of other disciplines, despite the efforts of a noble group of pioneers, of whom the greatest was certainly Paul Tannery. When George Sarton decided to launch *Isis*, a journal to be devoted entirely to the history of science, not all men of learning agreed that the idea was a good one. This was at once made evident to the youthful editor. Recognizing that he was young and without reputation, Sarton attempted to establish a board of sponsors. He asked the great French scholar Salomon Reinach, author of the well-known history of religions, *Orpheus*, to lend his name to the undertaking. Reinach refused, explaining that there was no need for such a journal; were there not already in print histories of mathematics, chemistry, biology, physics and astronomy? Had not the history of science been written?

Sarton's achievements are an answer to Reinach. The journal *Isis* has grown and prospered. Today it is the official organ of the History of Science Society, an organization of men and women all over the world who are engaged in research in this field. The journal, which Sarton still edits, has published hundreds of scholarly articles in many languages. Sarton has also regularly published for research workers semiannual critical bibliographies of all work done in the history of science and related fields. In addition, he has taught graduate and undergraduate courses in the subject at Harvard University to thousands of budding scientists and future scholars in this field.

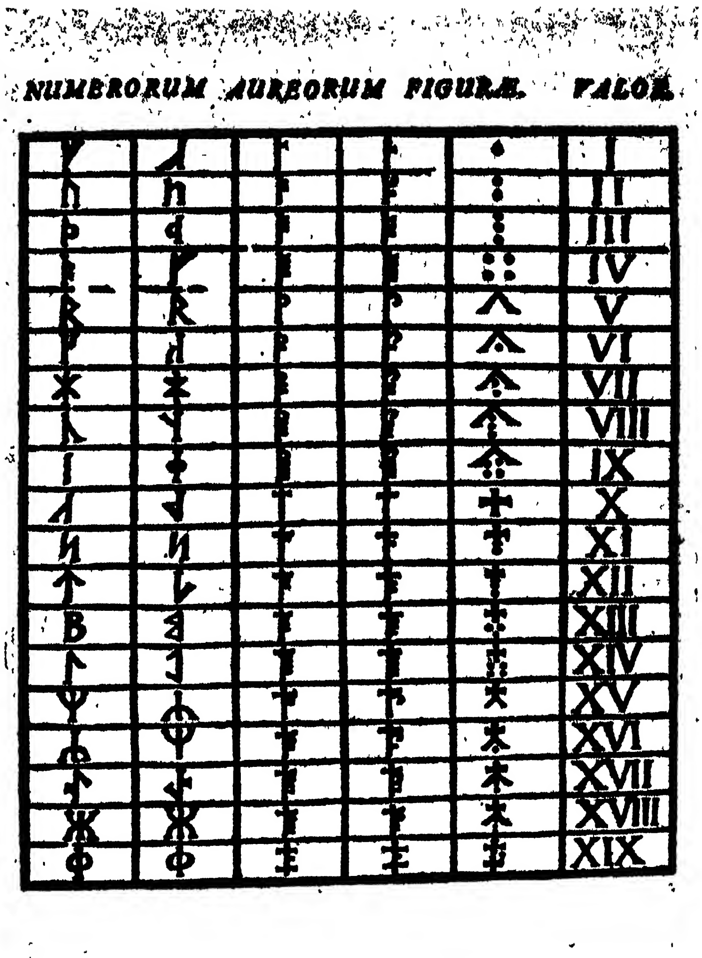
Sarton believed that there was still another huge task to be accomplished if the history of science was to be recognized as a serious and independent discipline. A handbook or guide was needed which would enable scientists and scholars to determine readily what had been done, when, and by whom. With this aim in mind, Sarton has singlehandedly composed a work that is unique in the annals of scholarship. Modestly entitled *Introduction to the History of Science*, it is an indispensable tool for the study of any aspect of the development of science (or, for that matter, of any aspect of the growth of human thought, culture and technology) from the time of Homer to the end of the 14th century. As the work has progressed, it has steadily grown in scope. A bare 839 pages sufficed for the period from Homer to the end of the 11th century; 1,251 pages were required for the next two centuries, the 12th and 13th. The present installment, dealing with the 14th century alone, is a two-volume work of 2,154 pages—as much as all the rest combined!

Sarton's aim may best be stated in his own words: "Perhaps the briefest way of intimating the general method is to compare my activity with that of a map-maker. Though I have taken considerable pains to insure the accuracy of every detail, however small, my main interest is not in any one of them, but in the whole structure. Even as the cartographer's purpose is to evidence the relation of the geographical facts, my main purpose has been to show the relations of the historical facts. This has never been done on the same scale, for no one has ever attempted to consider at one and the same time the progress of every branch of knowledge and the achievements of every nation. . . . I have tried to draw a map of . . . civilization which would be as complete and accurate as possible, and yet simple enough, sufficiently free from unessential details, sufficiently condensed, not to obstruct the general view."

The book opens with an over-all survey of science and intellectual progress in the first half of the 14th century. This first chapter of 350 pages, if printed separately, would make a splendid book by itself. It presents a sweeping, readable account of the general background of the period; the religious background (Roman Catholicism, the Eastern Church, Judaism, Buddhism, Hinduism): the translators and transmitters of knowledge: education; philosophy; mathematics and astronomy; physics, technology and music; chemistry; geography; natural history; medicine; historiography; law and sociology; philology.

This general introduction is followed by detailed chapters, averaging some 50 pages each, devoted to the 14 separate topics enumerated above. Each chapter contains succinct biographies and evaluations of every man who did intellectual work of any notable sort during the first half of the 14th century.

The biographies of Dante and of Petrarch, for example, are to be found under "philosophical and cultural background"; that of Bradwardine is under "mathematics." Often these biographies are further classified under such headings as Western Christendom, Eastern Christendom, Israel, Islam, India, China, Japan; no part of the globe is too remote to be



BOTANY of the 14th century is represented by this drawing of a specimen of sweet flag, an herb of the family Araceae, from a Chinese book of the period.

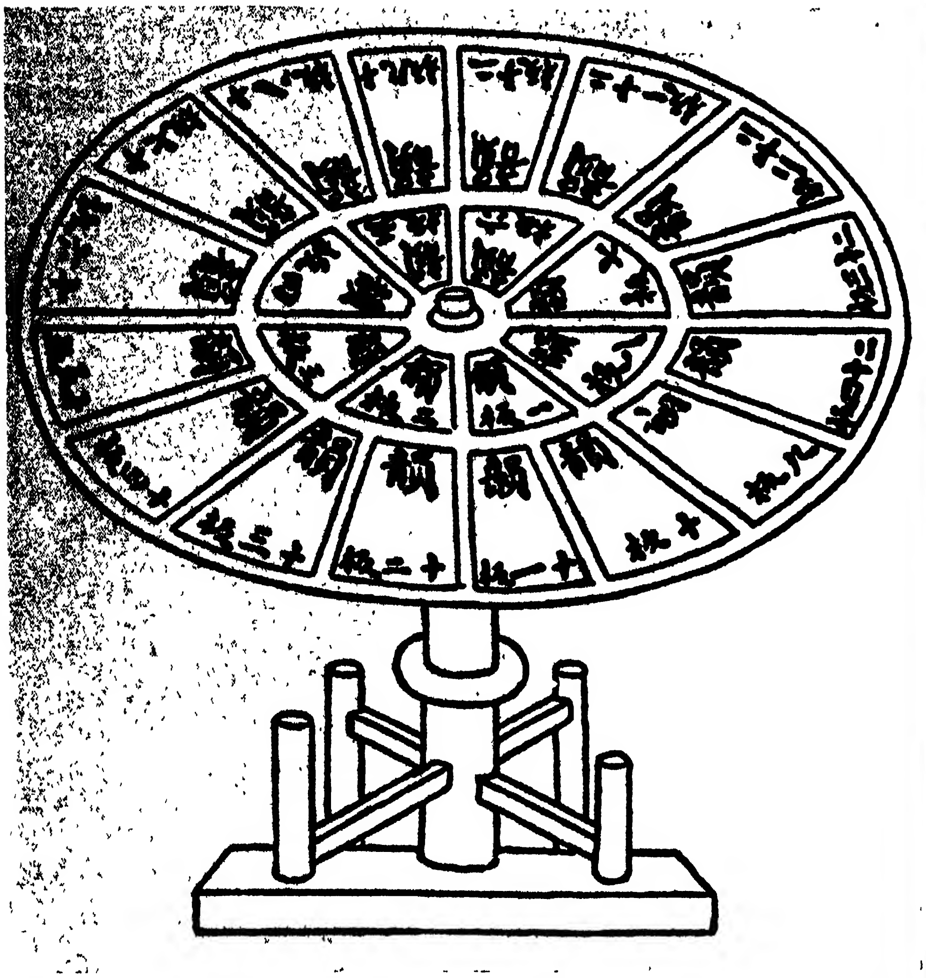
RUNIC NUMERALS of the Norsemen, preserved in this table of numbers from 1 to 19, show beginnings of a decimal system in northern Europe, *circa* 1300.

considered in this world map! In addition to the biographies, there are special articles on a myriad of subjects, such as technical improvements and their social import, Muslim music, civil calendars, the manufacture of glazes and ceramics in China, popular geometry in England, optics and optical meteorology, early mechanical clocks, the discovery of the compass, alchemy in Buddist Asia, Byzantine law. Jewish geography, canals. the development of printing in the East.

The word "biographies" is here used in a very special sense. Its meaning may be illustrated by the typical treatment of Pietro d'Abano, a famous Italian philosopher, astrologer, physician and translator. His biography occupies seven and a half pages, of which one short paragraph is devoted to his life and career. The rest is a careful analysis of his most important works, his reputation, his ideas, a list of his major writings and a bibliography of modern critical accounts dealing with all aspects of his life and career. Thus a scholar wishing to pursue the subject further is introduced to the texts of the subject and also the secondary and critical accounts. So the book is both an introduction to the development of science for the general reader, the historian and the scientist, and at the same time a starting point of research for the specialist and scholar. At the end of the book there are a general bibliography, a general index, a Greek index, a Chinese index and a Japanese index. By means of these indices, it is possible to follow any special topic throughout the book.

The foregoing outline of the anatomy of Sarton's book should give some impression of its vast scope. Especially valuable are the sections dealing with Jewish and Islamic scientists and thinkers. They contain much material not generally available to those who do not read Arabic, and richly illustrate Sarton's theme that there were three great streams of knowledge in the Middle Ages—the Jewish, the Islamic and the Christian—each of which has made its contribution to our scientific culture.

Considering the heroic scale of this work and the limited span of human labors, it may never be possible for Sarton to continue his record down to the present. Many will regret that one of the most magnificent undertakings in the history of the history of science may thus end before the rich and turbulent 16th and 17th centuries, when modern science as we know it took shape. But Sarton's students and the many scholars who have been inspired by him doubtless will continue where he leaves off, some amplifying the period that he has already covered, but more setting off into the last four centuries which his *Introduction* will probably never reach. Those who study the modern period will have to use a different method, since it is doubtful that Sarton's plan will work as well for the last four centuries as for the incubatory centuries preceding them. To cover even the 19th century on the scale adopted by Sarton for the 14th would require a team of scholars doing little else during their collective lifetimes, and the result would print to a size rivaling any respectable encyclopedia. In the modern period one would not want to devote quite so much attention to the background figures, to the poets, translators and theologians, nor to the general cultural aspects of a period which is better known to most of us. Moreover, in dealing with a period in which the lines of demarcation of human activity have become more sharply defined, it would not be rewarding to consider the sum of all human knowledge and all human creative en-



REVOLVING TYPE CASE to assist early printers was designed by Wang Chên, a 14th-century Chinese agriculturist, publisher and inventor. He used wooden type, which took ink readily and outlasted contemporary metals.

deavor beneath the heading of science.

In view of the great usefulness of Sarton's work to historians of all aspects of human culture as well as the history of science, we as Americans may be grateful for the good fortune that brought George Sarton to our shores from his native Belgium in the years of World War I; all men of learning and readers who are generally interested in science or in the development of human thought also will be grateful to the Carnegie Institution of Washington, which has supported his research and has sponsored the publication of the *Introduction to the History of Science*.

A work such as this depends on the labors of many people; a cursory glance at the bibliographies in Sarton's book shows how many different scholars and scientists have labored at the history of science. The history of science is far from being an exhausted field; indeed, as a serious discipline it is still young. There are enormous labors still to be accomplished. These include the editing, translating and interpreting of basic texts. No English edition yet exists, for example, of either Copernicus' great *De revolutionibus* or Vesalius' *De fabrica*. There are rich, untapped fields also in the biographies and collected editions of the letters and writings of the great men of science, in studies of the development of particular ideas or special subjects within the sciences and in periodic over-all surveys of the sciences.

A small and serious group of scholars are today busy at work increasing our knowledge of the history of science. Both in America and abroad, centers have been established to train the science historians of the future. And in recognition of the importance of a once-disdained field of activity, most of our leading colleges and universities now offer general courses in the history of science as well as in special phases of it. Meanwhile, the problem of educating nonspecialists in science has been given a radically new orientation with the realization on the part of educators that the history of science can be usefully employed in introducing science to the nonscientist.

As a sample of the kind of work now being produced by historians of science, we may also examine three different types of book. One is a biography of Copernicus entitled *Sun, Stand Thou Still*

(Henry Schuman, New York), by Angus Armitage. This is the first volume in a series that aims at "presenting to the lay reader, including young people of high-school and college age, the history of science, medicine and technology." The author is an eminent authority in the field; he had written a previous scholarly study on Copernicus and was trained both as an astronomer and a historian of science. *Sun, Stand Thou Still*, an easily read and exciting narrative, is an excellent introduction to the nature and significance of Copernicus' great achievement. The author also sketches in briefly the development of astronomy up to the time of Copernicus, so that the achievement may be grasped in its true historical setting. If this book is an adequate sample of what is to come in the series of which it is a part, the series promises to give scientists, students and general readers a true perspective on the great men and events in man's struggle to understand the physical universe around him.

One of the interesting aspects of the history of science is that so much of the work must still be done by nonprofessionals, not trained primarily in the young discipline of the history of science. Many of these scholars are primarily philologists, philosophers, scientists, historians of art or literature, general historians or even theologians. The field of the history of medicine especially is noted for the work done by general historians. *The Making of Modern Medicine* by Richard H. Shryock, whose field of work is nominally American history, has long been a standard work.

Now we have a new work on medical history, the posthumous *History of Medicine* (The Blakiston Company, Philadelphia), by the late Cecilia C. Mettler of Philadelphia. The volume was edited by her husband, Dr. Fred A. Mettler. Although not an M.D., Mrs. Mettler taught the history of medicine and has written her history with the aim of facilitating "the actual study of medicine." As a reference and source book, this new work is probably without rival; its bibliographies are long and inclusive and it contains a wealth of quotation from original sources, much of which was translated into English by the author herself. The work is compartmentalized into "specialties." following the customary distribution of subjects

FRANCESCO PETRARCH, the Latin poet and historian, though he distrusted scientists, is described in Sarton's panorama of the 14th century as "one of the founders of modern culture and indirectly of modern science."

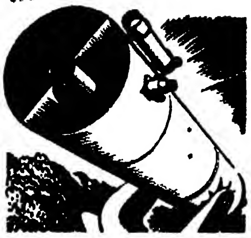
in the medical school curriculum, and each one is a self-contained unit that can be read without reference to the rest. The specialties include anatomy, physiology, pharmacology, pathology and bacteriology, physical diagnosis, neurology and psychiatry, venereology, dermatology, pediatrics, surgery and so on. Although useful for students and medical specialists, this form of organization tends to lessen its value for the general reader who is much more interested in getting a picture of the development of medicine as a whole. There is also a conspicuous lack of background material on related sciences, the cultural, social and general historical character of the times and even the relation of work in one field of medicine to that of another.

Of quite a different kind are two recent books by Charles E. Raven, Master of Christ's College and Regius Professor of Divinity in Cambridge University, England. The books are *John Ray, Naturalist* and *English Naturalists from Neckam to Ray* (both published at the University Press, Cambridge, and by The Macmillan Company, New York). While these biographies are primarily about naturalists, the author has presented his material in such a way as to illustrate and illuminate "the change in Western civilization from the medieval to the modern world"; the second book is subtitled "A Study of the Making of the Modern World." The erudition and great literary skill of the writer should make these fine books appeal to the general reader and to intellectual historians of thought as well as, of course, to naturalists.

The lives and works of these naturalists are related to their environment so clearly and penetratingly that readers will get a remarkably lucid picture of how the medieval view of the world was superseded by that of modern science. Professional and amateur scientists also will find in these volumes much valuable technical information about flora and fauna. Those who read these two important books will look forward to further works in Professor Raven's projected *History of Natural History in Britain.*

I. Bernard Cohen, instructor in the history of science at Harvard, is managing editor of the journal Isis.

DANTE ALIGHIERI, says Sarton, had "a remarkably good knowledge of astronomy" and was well versed in the physics, physiology and geography of his time. As a cultural influence, he dominated his awakening century.



THE AMATEUR

Conducted by Albert G. Ingalls

POSTWAR Switzerland is full of glass worms and is suffering from an epidemic of mirroritis. It is becoming a nation of glass-pushers and, no doubt, of long-faced glass widows. To put it another way, Switzerland is becoming addicted to the amateur telescope making hobby; "glass worms" is what the Swiss amateur telescope makers call themselves; "glass-pushers" are mirror grinders; "glass widows" are their deserted wives.

The Amateur Mirror Makers of Switzerland, with groups at Schaffhausen, Geneva, Berne, St. Croix, and isolated individuals elsewhere, have held national conventions. Through this column they transmit good wishes to their American fellow-addicts and/or fellow-sufferers.

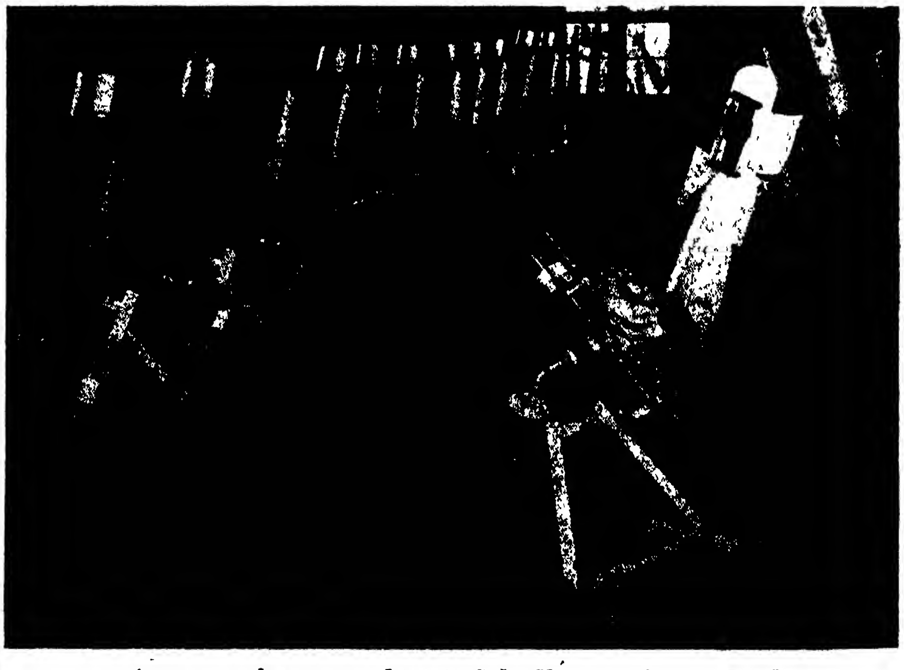
It began in a small way before the war when Hans Rohr of Vordergasse 57, Schaffhausen, Switzerland, acquired a copy of *Amateur Telescope Making* and wrote to this department. As his interest in telescope making continued, Rohr occasionally wrote again. During the war he made mirrors and lent his townsmen the only copy of *Amateur Telescope Making* then in Switzerland. He prepared, after the war, to inoculate his countrymen with the telescope-making virus.

This plot he carried out successfully. Mirrors have been made in Schaffhausen in classes of 21 participants, then 16, and later 12 in a community of only 23,000. There were mechanics, electricians, a confectioner, a newspaper correspondent, a mathematician, teachers, gardeners, mill workers, physicists, bookkeepers, students, chemists—people with much the same backgrounds as the amateur astronomers of the U. S.

No account of all these activities, long and faithfully reported to this magazine by Rohr, has previously appeared because details of the telescopes built were omitted, but these have now been sent. (Europeans show relatively less interest in mechanism than Americans do, but perhaps this is a more mature point of view. We go overboard on mechanism, and on group social activities, but we forget to use the telescopes we make—as do the more serious members of the British Astronomical Association. We seriously observe variable stars, but few who do this make the telescopes with which they observe.)

The mountings of the Schaffhausen telescopes are identical. They were designed and made by a group of engineers within the group and then sold to those who had made their own mirrors. When a nation of individualists like the Swiss, who have the largest number of inventors per capita of any nation, mass-produce their amateur telescopes, an explanation is required. The Swiss amateur telescope makers chose this approach to lower the cost so that more people could own telescopes.

The Schaffhausen mounting, which Rohr aptly calls the "ironing-board mount-



Amateur telescope making in Schaffhausen, Switzerland

ASTRONOMER

ing," is based on Russell W. Porter's simple design in *Amateur Telescope Making*, page 29. Porter's elementary design, however, is elaborated considerably. The base of the mounting is made entirely of wood and rests on two adjustable hand screws and a fixed support at the apex of the base triangle. When the base is lifted by means of a handle near the apex, the weight of the telescope is taken from the screws and shifted to two little wheels which at other times do not touch the ground. The telescope may then be trundled about like a wheelbarrow.

The polar and declination axes are of 1½-inch gas pipe, and are provided with adjustable conical nuts which also serve as bearings. Four steel cones, two for each axis, rotate in conical holes in large cubes built up of wood glued crosswise.

Each axis has its worm wheel and worm. The worm wheel is toothed around its entire diameter, permitting full freedom of movement. In the drive between the worm wheels and the shafts are friction slip rings which permit quick change in direction without the use of the slow-motion worm drives. The worm shafts are extended several inches on either end. This lends convenience. Springs on them take up end play. The "ironing board" of the tube is reinforced with a deep spine attached to it edgewise. At its lower end is a deep box with a hinged lid, which protects the mirror.

The eyepiece-adapter-prism unit, with three-point adjustment on the prism, may be moved along the axis of the ironing board by a slide, for focusing either quickly by hand or slowly by a screw. A curved metal sheet protects the prism and helps exclude extraneous light.

The finders are merely metal rings crossed by wires. These project from the end of the ironing board. Rohr says the telescope has proved to be very rigid.

In the background of the photograph on page 60 are three identical variations on the same theme. These are "twin baby carriages," each containing two six-inch mirrors and two eyepiece units, permitting two observers to study the same object simultaneously. These telescopes have proved to be too heavy and clumsy.

The Schaffhausen amateurs load their telescopes on trucks and concentrate them in public places to give their townspeople evenings with the stars. As many as 1,000 have attended these gatherings.

MAKING optical glass is like making beer; experience is an extremely important ingredient. Now, three years after the war, some of the long-established

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Teamwork is simply working together to turn out more goods in fewer man-hours—making things at lower costs and paying higher wages to the people who make them and selling them at lower prices to the people who use them.

What we've already accomplished is just a foretaste of what we *can* do. It's just a start toward a goal we are all striving to reach: better housing, clothing, food, health, education, with ever greater opportunities for individual development. Sure, our American System has its faults. We all know that. We still have sharp ups and downs in prices and jobs. We'll have to change that—*and we will!*

It will continue to take *teamwork*, but if we work together, there's no limit on what we can all *share together* of even greater things.

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Sirs:

The sudden outburst of talk recently about population increasing faster than the food supply is one of the most curious paradoxes of our paradoxical times. Starvation in the midst of plenty characterizes the postwar period at the moment when potential productivity has grown beyond the possibility of accurate prediction. Yet at this moment economic man turns back to the old classics, instead of rising imaginatively to the new economics suitable to the new methods of production.

Malthus first enunciated the formula that population increases faster than means of subsistence. He lived in the years from 1766 to 1834, when the industrial revolution of steam, with capitalism as its economic system, was supplanting the older system of feudalism. The population was being driven from the land to cities. The land had to feed not only those who tilled the soil, but also city dwellers. Moreover, the new system of production was not yet as productive as it was destined to become.

Today we are witnessing a tremendous acceleration in potentialities of means of production. Science can now change the condition of the soil and produce vastly more food. Among many studies which might be cited is the paper prepared for the World Social Economic Congress held in August, 1931, at Amsterdam, Holland. Dr. Otto Neurath, sociologist of Vienna, presented in visual form the increase in productive capacity of the world, and concluded that "Malthus was wrong" and that in our day productive capacity has increased faster than population.

But war and the economics of war have burdened production with debt, besides wasting resources and imposing such severe shortages in many parts of the world that starvation, rather than abundance, characterizes the present decade, while unprecedented unemployment and depression were the experience in the 1930's. It is clear today that man's wastefulness is responsible for failure of means of subsistence to keep pace with population. Planned abundance, which is actually the objective of the peoples of the world today, can produce standards of living far beyond the possibility of imagination in Malthus' day. At the same time, raising of living standards, material and cultural, would certainly result in planned population. This does not necessarily mean a check to present rates of growth. It should be observed that *rate* of growth, as con-

LETTERS

trasted with actual growth, either of population or of production, tends to decline. There seems to be no scientific basis for indicating that a given rate of growth of population will continue into the future. Likewise, there is certainly no reason to assume a static condition in means of subsistence. It appears today that both population and production are destined to increase.

It is to be hoped that the new assertion of Malthusianism will be countered by carefully developed interpretation of social and technological data concerning population and world resources today. The purpose of this letter is merely to give expression to the widespread protest against these recent pronouncements, and to call attention to the evidence against them. The false doctrine which Malthus himself might have repudiated can certainly not win scientific adherence. It is merely one more indication that social and political thought lag behind technological development.

MARY VAN KLEECK

New York, N. Y.

Sirs:

The article in your July issue by Frederick A. Saunders on "Physics and Music" appealed to me very strongly, and was so full of interest that nothing additional seemed necessary. But the letter from Marie Mikova in your September issue, taking issue with Dr. Saunders' statement that the tone of a piano is the same whether the key is pressed by a great artist or the tip of an umbrella, prompts me to add a few words in defense of Dr. Saunders.

The performer at the piano is free to make two choices, and only two. He may determine the intensity of the sound by determining the velocity with which the hammer meets the wire, and he may determine its duration by determining the length of time he keeps the key depressed. Thus intensity and duration are directly under the performer's control, although if he strikes the key with an instrument other than his finger this control may be somewhat impaired. On the other hand, pitch and tone are not under the performer's control but are inherent in the instrument.

If the performer releases a key a perceptible time before depressing the next one, so that a hiatus of silence occurs between the two notes, he is said to be using a staccato touch; if he releases one key and depresses another simultaneously so that no hiatus of silence can occur, he is said to be using a legato touch. Judicious use of the damper pedal makes it possible to combine a staccato touch with a legato effect. If a long succession of otherwise legato notes be broken up by the insertion of judiciously placed staccato notes into a series of groups, the passage is said to be phrased. The older classical writers frequently did not indicate the phrasing very precisely, but left it to the judgment of the performer, with the result that modern editions of Bach, for instance, exhibit considerable divergence in their phrasing. Differences in phrasing produce different sound effects, especially in passages in which dissonances predominate. But these differences are not tonal; they are stylistic.

My own feeling is that Miss Mikova, being a pianist herself, is very sensitive to minute variations of phrasing and intensity, which she hears accurately, but which she mistakes for tonal differences.

There is one conceivable way in which a pianist might alter the tone of a piano while playing it. That is by the use of the so-called "soft pedal." On most grand pianos, but not all, this pedal shifts the keyboard laterally, so that the hammers strike only one wire, leaving the other two to vibrate sympathetically, and it is not impossible that a wire vibrating out of sympathy might produce a different tone from that produced by a wire that had been percussed, but if so this difference must be very slight. I cannot distinguish it myself, and I doubt if anyone else can do so.

But in any case, Dr. Saunders has not maintained that the pianist cannot alter the piano tone, but only that he cannot do so by means of varying his touch.

JOSHUA L. BAILY, JR.

San Diego, Calif.

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50 AND 100 YEARS AGO

NOVEMBER 1898. "Mr. Axel Danielson, a correspondent of Stockholm, Sweden, is keeping us informed as to the status of the Nobel bequest. He says that the case has been decided, or rather a compromise has been effected between the contesting parties. The relatives of the deceased will waive 3.800,000 Swedish crowns, a little more than $1,000,000, so that there still remains for the prizes the sum of 25.000,000 crowns, equivalent to $6,950.000. The income, computed at the rate of three per cent, will make the five prizes worth 150,000 crowns or $41,600 each. It will be remembered that these prizes are to be awarded annually to persons making the most important discoveries in physics, chemistry, physiology or medicine. There is also to be a prize for the best literary contributions upon the subject of physiology or medicine, and also one for any person who has achieved the most or done the best things working toward the cause of the promotion of peace throughout the world."

"Mr. Nikola Tesla, of New York, has invented what is known in naval science as a dirigible torpedo which, instead of being self-driven and self-steering, like the Whitehead and Howell torpedoes, now in use by our Navy, is driven and steered by an operator on shore, who controls the torpedo through electrical connections. The most characteristic feature in Mr. Tesla's torpedo as distinguished from others of the dirigible class is that, whereas they use a connecting cable for transmitting the controlling power to the torpedo, he makes use of the Hertzian waves, dispensing with the cable. This method of transmission is more popularly known under the name of 'wireless telegraphy,' and as such attracted considerable public attention during the recent experiments by the British Post Office and the apparatus designed by the young Italian, Marconi."

"Next to the test of actual war, no stronger endorsement of the excellence of a nation's warships can be desired than the fact that its shipbuilding yards are patronized by foreign governments. The first foreign orders placed in the United States for warships of the modern type were those given by the Japanese government to the Union Iron Works, of San Francisco, and the Cramps' Shipbuilding Company, of Philadelphia, for two high-speed cruisers. Following closely upon the successful trial of these ships has come an order to the Cramps' yard for the construction of two first-class ships—a battleship and a cruiser—for the Russian government."

"One of the most astonishing features in the development of modern journalism is the magnitude and audacity of the Sunday issues of the great daily papers, and among these there are none that are quite so successful as those issues which are marked by the distinctive characteristics of yellow journalism. Now the yellow journal, in its quest for startling novelties to whet the palate of its readers, invades every possible sphere of human life and interest and every branch of human knowledge. Science, which, one would have thought, would be severely let alone, is a favorite hunting ground of the reporter, and whole pages of the yellow-journal seventh-day editions are loaded down with pseudo-scientific pabulum. The reporters for these journals are apparently sent out into the domains of science charged with a commission to magnify mole hills into mountains."

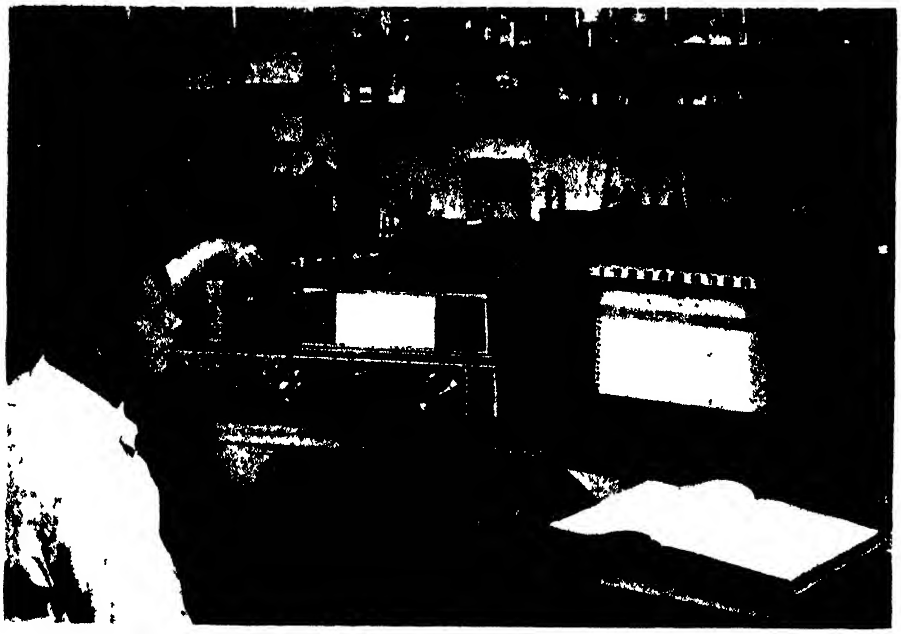
NOVEMBER 1848. "Up to the hour of our going to press election returns from over twenty different States had been received in this city by the Electric Telegraph. General Taylor has received overwhelming majorities in almost every State as yet heard from, and his election is unquestionable. The readers of the SCIENTIFIC AMERICAN may consider it settled that 'Old Zack' is now the President elect. He will be inaugurated on the 4th of March 1849, his term of office expiring in 1853. May he not prove unworthy of the confidence reposed in him!"

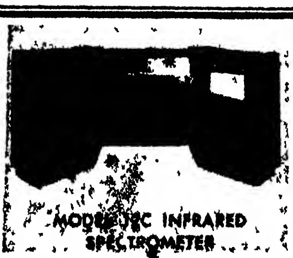
"Some have endeavoured to detract from the merit of Prof. Morse as the inventor of the Electro Magnet Telegraph, and make him indebted to Dr. Jackson of Boston for all his information, he being a passenger on the ship Sully with Prof. Morse in 1832, and used to converse with him on the subject. It would have looked more çandid if Prof. Morse had mentioned the name of the *passenger* with whom he used to converse on the subject while on his voyage from France in 1832. Yet what of all this, we have no evidence that Dr. Jackson ever constructed an electric telegraph, and although Prof. Henry gives tardy praise to Mr. Morse, the names of great scientific men should not be allowed to weigh as a feather in the balance against a successful inventor but a less distinguished man of science. For more than 30 years Sir Humphrey Davy had the world wide honor of being the first inventor of the Safety Lamp, and it was not till the summer of 1848, that the inventor, Geo. Stevenson the mechanic, was acknowledged before a high Scientific Association."

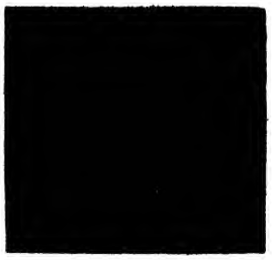
"Two years ago it was announced to the unlettered world that Le Verrier, a French astronomer, had by the dint of sagacity and calculation alone, discovered a new Planet which was named Neptune. A new planet was discovered, but American astronomers declared that it was not that pointed out by Le Verrier. There has been a controversy on this subject among the astronomers of the two worlds, and various reports have gone abroad which have shorn the French astronomer of no small amount of his sudden and high honors. But we perceive by a discussion that took place at the Paris Academy of Science on the 14th of Sept., that Le Verrier ably confounded Mr. Babinet, another astronomer, who held views opposite to the discoverer of Neptune."

"Twenty-three years ago the utility and usefulness of the locomotive were doubted by the most practical and scientific men of the age. In 1814 the speed of George Stephenson's Kilinsworth Engine was 4 miles per hour. In 1825, only twenty-three years ago, Mr. Wood in his treatise on the railway system takes the standard speed at six miles per hour, drawing on a level a load of 40 tons. In 1829 the highest speed attained was 29 miles per hour—working speed 10. In 1848 the highest speed attained is 75 miles—working speed 55. How striking the contrast. In 1829 the maximum load of the Locomotive Engine was nine tons--in 1848, less than 20 years, it is 1200; the highest speed then 15 miles, now 75, and in one instance 84 miles per hour."

"Sir John W. Lubbock, according to the hypothesis, adopted by him in his Treatise on Heat of Vapors, shows the density and temperature for a given height above the earth's surface. According to the hypothesis, at a height of fifteen miles the temperature is 240° Far. below zero; the density is .03573; and the atmosphere ceases altogether at a height of 22.35 miles. M. Biot has verified a calculation of Lambert, who found, from the phenomena of twilight, the altitude of the atmosphere to be about eighteen miles."







THE COVER

The painting on this month's cover, made by the astronomical artist Chesley Bonestell, shows the sun *(see page 26)* as it might appear from a point above the baked surface of the planet Mercury. Because Mercury has no atmosphere, the features of the sun would shine with a harsh brilliance never observed on the earth. Planets and other stars would also sparkle in the jet-black sky of Mercury's day. At the lower right is the small constellation of the Pleiades, surrounded by its faint nebulosity. At the upper left is the red planet Mars. Visible on the disk of the sun is a large group of sunspots. From the edge of the disk flare great yellow prominences. About the disk is the gray mantle of the corona, clearly seen on earth only during a total eclipse of the sun. Within the corona are the faint lines of force of the sun's magnetic field. Above and below the corona is the ellipse of the zodiacal light, presumably made up of a vast swarm of tiny meteors rotating about the sun at high speed.

THE ILLUSTRATIONS

Cover by Chesley Bonestell

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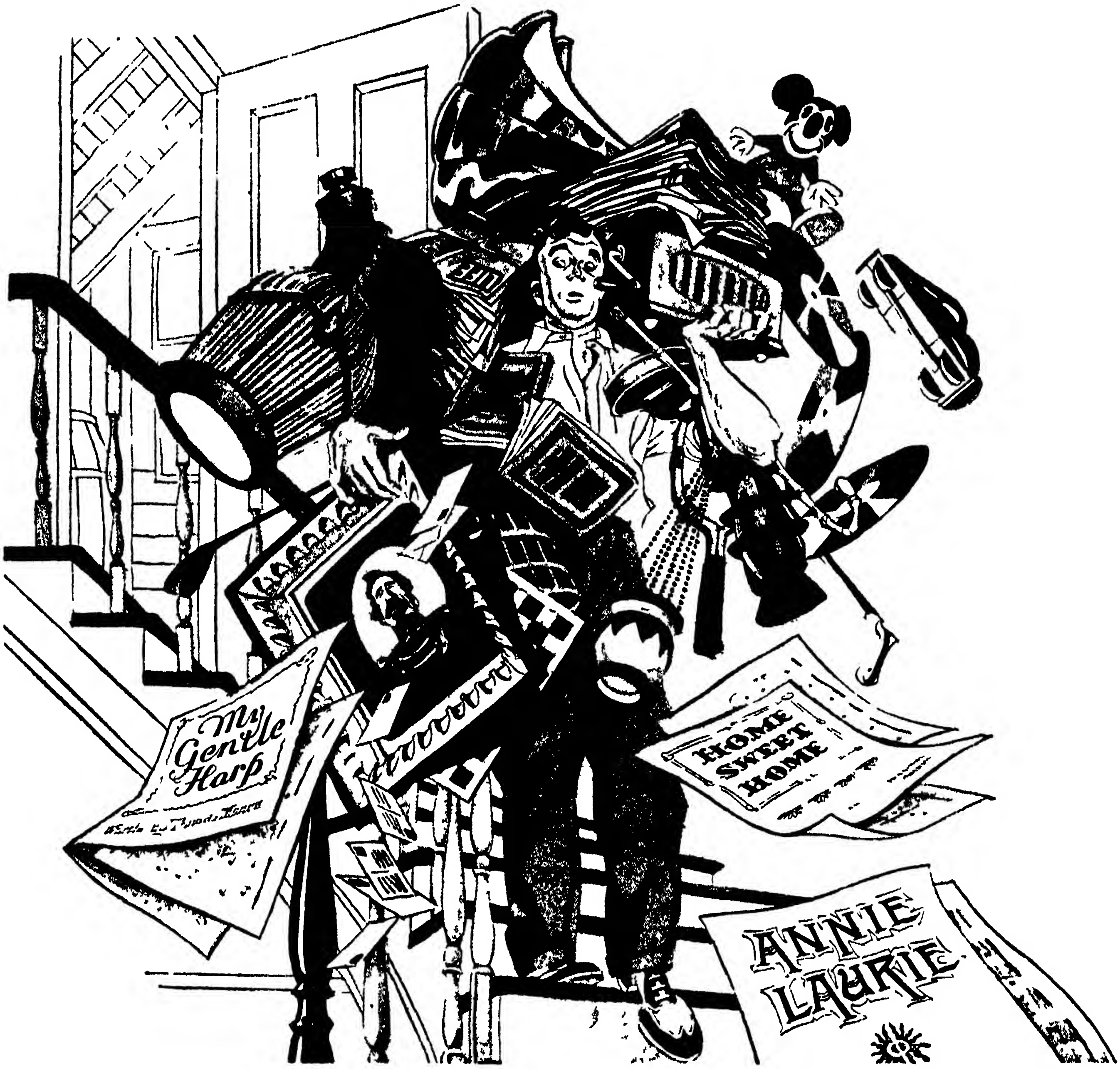

Best way to put *out* a fire

PUT IT WAY OUT—out of the attic and into the alley, before it ever gets started. Keep closets, attics and cellars clear of rubbish and oily rags. Check home electrical wiring frequently. Handle matches carefully and keep them out of children's reach. This is how you can help prevent the thousand home fires a day that kill 5600 persons annually in the United States.

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NOVEMBER 1948 VOL. 179, NO. 5

LABRADOR IRON

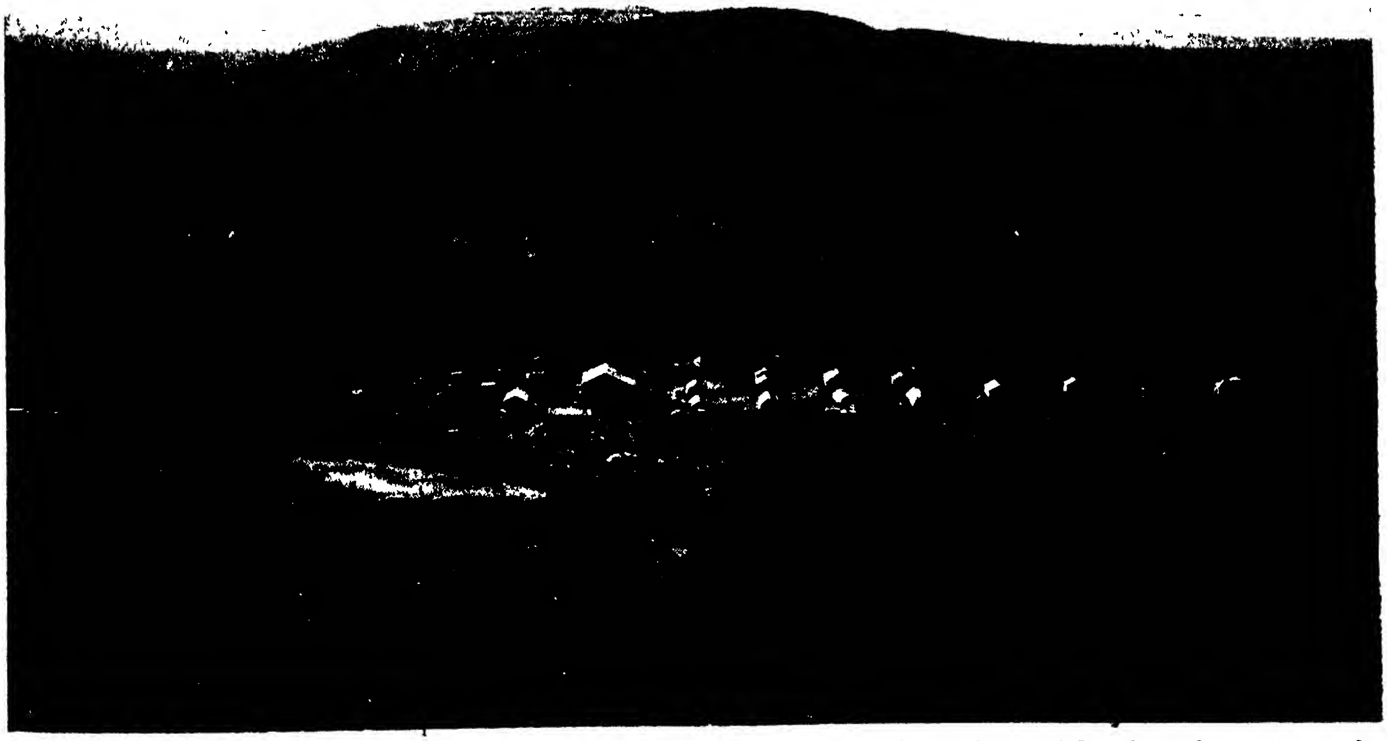
The red rock of the bleak northern province may be a part of the solution to the coming shortage of ore for the U. S. steel industry

by Herbert Yahraes

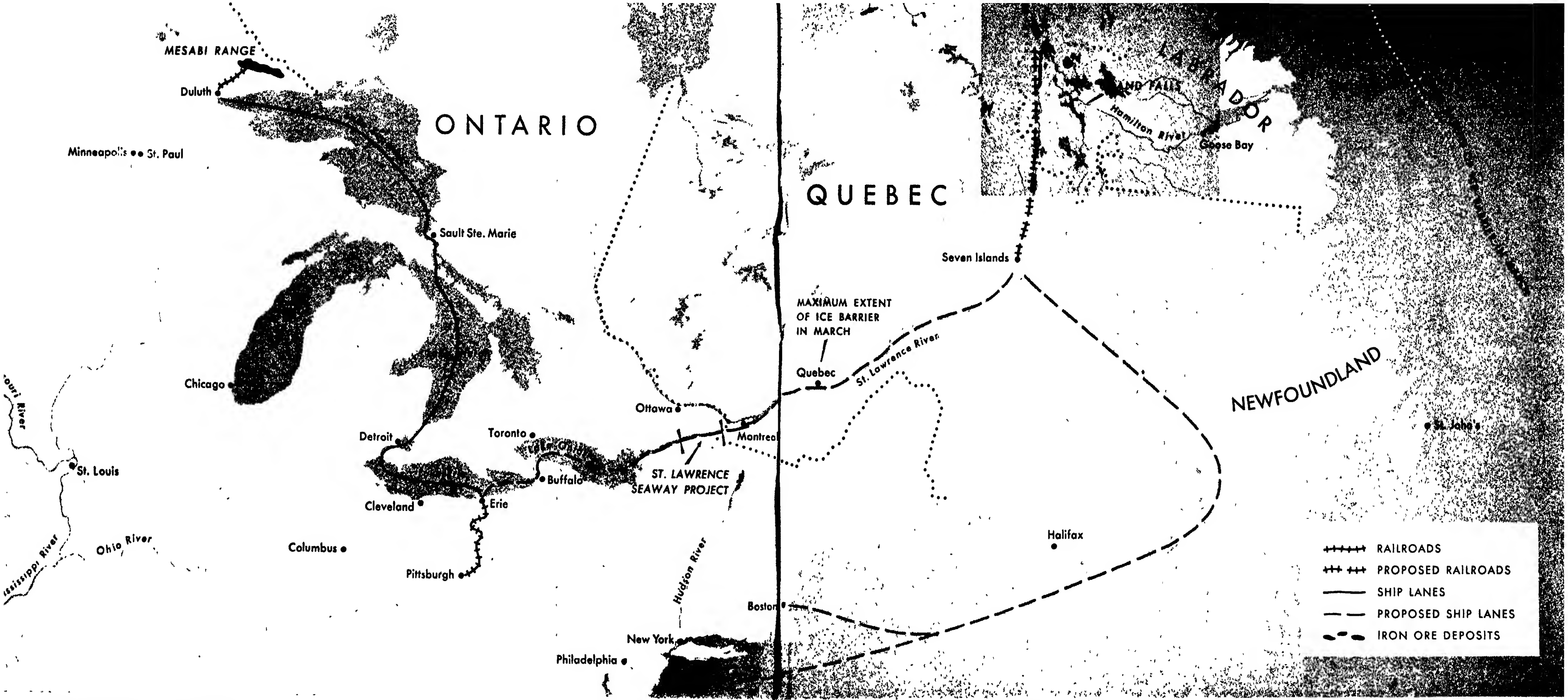
IN the rolling hills of northeastern Minnesota yawns a man-made excavation that for scenic splendor has been compared with the Grand Canyon. Great streaks and patches of color—purples, yellows, browns—blend into one another down its tiered sides. The vast excavation, three miles long and in some places a mile wide, is gouged 400 feet deep into the rocks. And it constantly grows as big steel shovels crawl along its cliffs taking many-tonned bites at what is left of some of the world's richest earth.

This is the Hull-Rust-Mahoning, the largest open-pit iron mine in the world, the biggest producer of the fabulous Mesabi Range. From this one pit alone during the war were taken 25 million tons of high-grade ore a year—more than a fourth of the total U.S. production.

For half a century the Mesabi—which is Ojibway for giant—and the lesser ranges of the Lake Superior district have been supplying 85 per cent of the iron ore used in the U.S. Twice they have enormously expanded their output to see the nation through great wars. But the spurt in World War II was exhausting; many mineralogists now consider the Mesabi a dying giant. The production of the Hull-Rust-Mahoning fell to 16 million tons in 1946, and even less in 1947. The rich, easily accessible ore is giving out; from now on the big shovels will have only the bones to pick at. Estimates of the Lake Superior reserves run to something more than a billion tons. A noted economic geologist, W. O. Hotchkiss, gives the ranges 21 more years at the outside; the



BASE CAMP for the geological exploration of Labrador iron is at Burnt Creek, near the boundary between Labrador and Quebec. The land has been burned over by fires and much of the soil scraped away by glaciation.



ORE FOR STEEL INDUSTRY is presently carried by boats from Duluth (*upper left*) to Erie and other lake ports north of Pittsburgh. If the railroad from the Labrador deposits is put through, ore can also be shipped from the St. Lawrence port of Seven Islands. Until the St. Lawrence Deep Waterway is built, however, Labrador ore must be carried to the lake ports in small ships. Large ships will be able to carry it only to Atlantic ports.

open-pit mines, the heaviest producers, will be exhausted within a decade.

All this has caused the multi-billion-dollar steel industry—and the U.S.—considerable concern. C. M. White, president of Republic Steel, observes: "The industry as a whole faces dire shortages in a period too short to be comfortable." The steel industry, which from furnaces to fabricating plants has been built almost entirely around the Mesabi Range and its neighbors, has been compelled to consider some revolutionary alternatives.

One possibility is to find some practical way of utilizing the Mesabi's vast but hitherto useless deposits of the iron-containing rock called taconite. Taconite can be converted into usable ore by a process known as beneficiation. But this alternative would be, extremely costly. Open-pit ore, on which the steel industry has been built, is mined in one step and fed to the iron furnaces without further treatment. The conversion of taconite into usable ore takes 12 steps, and a ton of taconite makes only a third of a ton of furnace feed. In the present stage of technological development, a plant capable of producing from taconite one million tons of ore a year—one per cent of our needs during World War II—might cost up to $10 million, and the production of usable ore would take several times as many miners and technicians and immensely more power than is now required.

Another alternative is to uproot the whole steel industry from the Great Lakes region, where nature has fortuitously provided handy coal supplies and waterways for cheap transportation of the Mesabi ore, and to transplant it along the Atlantic or the Gulf Coast. Then the industry could afford to use imported ore, mostly from Latin America. This idea may seem fantastic, but it would be unreasonable to suppose that an industry that could build a Pittsburgh could not lift it up and set it down by the Atlantic. Whether it would be advisable to concentrate any more vital industries along the eastern seaboard, however, is another question.

Steel men as a group have been casting about to find a solution in some combination of these possibilities. Bethlehem Steel, for instance, already has a huge plant at Sparrows Point, Md., using ore from Chile and Brazil. Two companies are already producing ore from taconite, and others are getting ready to do so. In addition, several large steel companies are exploring the almost-forgotten but sizable deposits in the Adirondacks of New York State.

NONE of these possibilities is greatly encouraging. But there is now under investigation another alternative which seems breathtaking in its potentialities. It arises from the discovery of immensely rich deposits of iron in Labrador. Labrador iron is an old story; the existence of an ore formation on the peninsula has been known for more than half a century. But only recently have its possibilities been seriously explored. As the result of intensive studies during the past two years, geologists now believe that the Labrador range may contain as much high-grade, open-pit iron ore as one, two or perhaps as many as five virgin Mesabis.

This development must naturally be considered with caution. It is one thing to discover iron and another to get it out conveniently. Whether the iron ore of distant, frigid Labrador constitutes a practical answer to the steel industry's needs is already a matter of considerable controversy among steel men. Nonetheless, the effort to solve the practical problems involved is proceeding with vigor and determination.

The Labrador formation was first noted in 1892—the year the Mesabi was opened—by a Canadian Government geological survey. There was no actual exploration of the deposits, however, until 1929. The area was so remote from good supplies of coal and the climate so rigorous, the thermometer sometimes dropping to 40 degrees below zero, that surveys seemed a waste of time. "Everywhere in Labrador the physically weakest still go to the wall," wrote Sir Wilfred Grenfell in *The Romance of Labrador* in 1934. "No white man is yet able to make a home in the interior, where the only law is still the immemorial code of the hunting ground. The high interior, scrubbed bare of soil by the ice ages and burned over by the great fires, can only become a white man's country when the wealth of its minerals justifies the expense of supplying his needs from the outside."

In 1942 the owners of Canada's largest gold mine began assaying that wealth. Hollinger Consolidated Gold Mines, Ltd., buying control of the earlier-organized Labrador Mining and Exploration Co., acquired sole rights to prospect and develop

a large area in the central part of the peninsula. The Hollinger firm was joined in this enterprise by one of the largest independent ore producers in the U.S., M. A. Hanna Co. of Cleveland.

The work went slowly. Geologists and engineers and their food and equipment had to be flown in, for the nearest road ended 400 miles away. Operations were limited to the summer. Discovering that the iron deposits extended into Quebec, the Hollinger interests set up another subsidiary, the North Shore Exploration Co., to follow the ore across the border.

Few hints of this work on the continent's newest frontier have trickled through to the public. Most steel men have viewed it as a distinctly long-range project at best, and even Hollinger-Hanna officials emphasized that before spending the scores of millions of dollars needed to develop Labrador iron, they would require proof of reserves running to at least 300 million tons—equivalent to at least a three-year supply for American furnaces from all sources.

How far the prospectors have progressed toward that goal is not known; precise figures on the amount of ore proved this year are not available. But the explorations are known to be well ahead of schedule, and it is possible that the 300 million tons may be proved this year.

The Hollinger concessions cover 22,000 square miles straddling the Labrador-Quebec boundary. The area takes in part of an iron-bearing formation which is at least 300 miles in length, according to the Bureau of Mines of the Canadian Government. One estimate reckons the total length of the iron-bearing formation as 500 or 600 miles; the Mesabi formation, by contrast, is only 112 miles long. Moreover, in Labrador the formations are repeated in folds across a width of 30 miles, so that instead of a single strip of iron ore, as in the Mesabi, there is a series of parallel strips.

Geologically, the Labrador-Quebec ore is the same age as the Mesabi's, dating back to the pre-Cambrian period, and its deposits were formed by much the same geological processes. Presumably the Labrador site, like the present mining sites of the Lake Superior region, was once covered by a great sea, in which iron—one of the most widely distributed of the elements—and other materials were deposited by tributary streams. Pressure and heat transformed this iron-bearing sediment into rock, and massive earth disturbances raised it to the surface.

Much of this original sedimentary rock, at least in the Lake Superior region, remains as taconite, the iron content of which is relatively low—from 20 to 35 per cent. The higher-grade ore was created by the action of underground water, which over the ages leached out much of the silica in the rock and in some places enriched it by precipitating iron oxide. Some of the Labrador ore, like the Mesabi's, is high-grade hematite, or ferric oxide. But most of it is a blue-brown mixture of hematite, limonite and goethite.

High-grade ore is defined as ore with an iron content of more than 50 per cent and not too high a silica content. In recent years the iron content of Mesabi ore has averaged about 59 per cent. The Labrador peninsula iron seems to be at least as rich. Samples from 11 ore bodies in Labrador, the Hollinger interests reported two years ago, averaged 62.1 per cent of iron in dry ore, and from 11 deposits in Quebec, 61.2 per cent. Both included some manganese. A more recent report on 10 deposits shows Bessemer ores averaging better than 62 per cent and non-Bessemer ores about 58 per cent. In addition, deposits of manganiferous ores have been found with an iron content better than 50 per cent and a manganese content running up to 8 per cent. Manganiferous ores are highly prized by the steel industry.

Like the Mesabi ore, Labrador iron lies close to the surface and can be mined by open-pit operations. Indeed, the Labrador ore may be even easier to dig, for in this region the glaciers scraped the iron-bearing strata bare, while in Minnesota they covered the Mesabi with sand and rock to an average depth of 70 feet, necessitating costly stripping operations.

Almost all of the ore found so far in Labrador has been in surface outcrops. The thickness of the deposits is unknown, but it is believed to range from 300 to 1,000 feet; tunnels 200 feet long and 100 feet deep have been driven through two of the ore bodies. The prospecting so far has been done in only a tiny portion of the vast Labrador and Quebec concessions, and development work has been restricted to those deposits which not even an amateur geologist could miss.

FROM the geological standpoint, then, the Labrador-Quebec discovery seems an ideal answer to the steel men's problem. The big drawback lies in the region's relative inaccessibility. The Government of Quebec hopes eventually to see furnaces built close to the ore bodies, using hydroelectric power instead of coal for fuel.

Coke for reducing the ores, however, will still be lacking. In any case, if the new field is to assume even part of the burden the Mesabi must surrender, the ore will have to be carried to furnaces in the U.S.

A major problem, therefore, is building the necessary transportation facilities. The first step will be the construction of a 360-mile railroad from the Labrador wilderness to the Gulf of St. Lawrence; this distance is three and a half times that from the Mesabi to Lake Superior. With modern earth-moving machinery such as was used to build the Alaska highway, engineers expect no unusual trouble in pushing the rail line through, but the cost of construction, of rolling stock and of the necessary port facilities will approach $100 million.

The Hollinger-Hanna group already has a railroad charter from the Dominion Government and within the past two years has surveyed the entire proposed route. It has also studied port sites. By the spring of 1949 detailed construction plans are expected to be largely completed. The present plan is to locate the rail line along the Moisie and Wacouna rivers, running almost due south from the heart of the deposits to the Gulf of St. Lawrence. There port and ore-loading facilities are expected to be placed at or near Seven Islands. According to the Canadian Government, ore boats could use the St. Lawrence during most of the winter—which would mean a longer season than on the Great Lakes—and there is some hope that an icebreaker might keep the St. Lawrence port open the year round.

To construct and operate the rail line, the development group set up the Quebec North Shore and Labrador Railway Co. in 1947, and to develop and distribute hydroelectric power—for mining operations and possibly for electrifying the railroad—they formed the Ungava Power Co. An excellent power site is available on the Kaniaspiskau River only 30 miles west of the northwestern edge of the ore deposits.

The headquarters of the project is now at Burnt Creek in Labrador, close to the Quebec line. An airstrip, 100 miles of roads, shops, a laboratory and housing for 150 men have already been built, and plans have been made to build two towns, one in the ore field and the other at dockside at Seven Islands, to house future workers. The supply line to the Burnt Creek camps now runs down the St. Lawrence to Seven Islands and Mont-Joli by boat, and thence northward by plane.

The river valleys in this region are forested, assuring enough local timber for construction and mining purposes, but the uplands have only a sparse cover of scrub and moss. Drifting snow settles deeply in the hollows. In spite of the snow, a Hollinger crew spent last winter at Burnt Creek, getting out timber for a sawmill and making other preparations for the 1948 season. They found it possible to keep the needed roads open. A government engineer says that weather conditions "will certainly not prevent such winter mining operations as may be required when full-scale mining is under way."

Thus the activities in the new field since the spring of 1947 seem to have answered satisfactorily two of the big questions. The ore is there—in quantities and grades that may make the Labrador-Quebec deposits the richest ever found. And it can be got to water. Transportation costs, taking into account the favorable downhill grades to the St. Lawrence which would permit long ore trains, are estimated at $1.75 a ton from mine to port. This would be twice the rail cost of transporting Mesabi ores to the Great Lakes, but Canada's

lower taxes and royalties may more than make up the difference.

A large question, however, remains: Where does the ore go once it reaches the St. Lawrence? On that question may hinge both the usefulness of Labrador iron and the future of the steel industry.

Some of the ore will certainly move down the Gulf and into the Atlantic to supply present smelting furnaces along the seaboard. One authority estimates this potential market at one million tons a year—a minuscule amount compared with our total needs. Another suggestion is that the ore could be made reasonably accessible to the Great Lakes by water. How by water? The vessels that can now use the St. Lawrence and Welland canals and thus enter the Great Lakes from the east are limited in capacity to 3,000 tons; the great ore carriers that move down from Minnesota hold five times as much.

The answer, of course, lies in the proposed St. Lawrence Deep Waterway, which would make the cost of delivering the new iron to buyers in Pennsylvania and Ohio not greatly different from that of delivering the output of the Mesabi and its neighbors. While the distance to Cleveland from Duluth, for instance, is about 200 miles less than from Seven Islands, Canadians are counting on a higher-grade ore to compensate amply for the longer water haul.

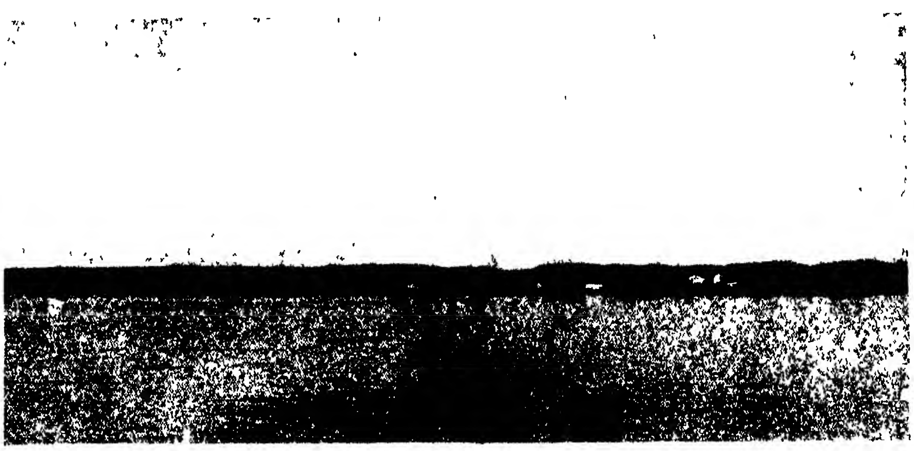
The Deep Waterway, however, is still only a blueprinted dream. It is fiercely opposed by eastern seaports and other interests, and only a few months ago Congress shelved it once again. The steel industry is divided on the question. M. A. Hanna, long an opponent of the Waterway, now considers it necessary for the maintenance and expansion of the steel industry. Other steel makers hold that the $500 million which the Waterway would cost the U.S. should be spent in subsidizing beneficiation plants in the Lake Superior region.

The Waterway was projected decades ago to bring the wealth of the continent's interior to the seaboard. The time may come when, ironically, the Waterway will have to be completed for exactly the opposite reason: to bring the wealth of seaboard mines to the continent's interior.

In five years, possibly less if an emergency arises and construction work is rushed, iron ore is expected to begin to come from Labrador in commercial quantities; in a few years shipments very likely could reach the first objective of 15 million tons a year. In the long run we shall probably have to duplicate quickly, cheaply, and on a grand scale the process by which nature converted taconite into high-grade ore. Meanwhile Labrador-Quebec iron offers, at the very least, a breathing space.

Herbert Yahraes is a science journalist.

GREAT WATERFALL on the Hamilton River, almost twice as high as Niagara, is one of many possible hydroelectric sites in Labrador. Quebec Government has suggested using electric power to smelt iron at source of ore.



TERMINUS OF RAILWAY to carry ore south from the Labrador fields would be at Seven Islands. From here the ore could be shipped west up the St. Lawrence to Lake Erie ports or southeast to the ports of Atlantic Coast.

CYBERNETICS

The word describes a new field of study shared by many sciences. Among other things, it looks into the processes common to nervous systems and mathematical machines

by Norbert Wiener

CYBERNETICS is a word invented to define a new field in science. It combines under one heading the study of what in a human context is sometimes loosely described as thinking and in engineering is known as control and communication. In other words, cybernetics attempts to find the common elements in the functioning of automatic machines and of the human nervous system, and to develop a theory which will cover the entire field of control and communication in machines and in living organisms.

It is well known that between the most complex activities of the human brain and the operations of a simple adding machine there is a wide area where brain and machine overlap. In their more elaborate forms, modern computing machines are capable of memory, association, choice and many other brain functions. Indeed, the experts have gone so far in the elaboration of such machines that we can say the human brain behaves very much like the machines. The construction of more and more complex mechanisms actually is bringing us closer to an understanding of how the brain itself operates.

The word cybernetics is taken from the Greek *kybernetes*, meaning steersman. From the same Greek word, through the Latin corruption *gubernator*, came the term governor, which has been used for a long time to designate a certain type of control mechanism, and was the title of a brilliant study written by the Scottish physicist James Clerk Maxwell 80 years ago. The basic concept which both Maxwell and the investigators of cybernetics mean to describe by the choice of this term is that of a feedback mechanism, which is especially well represented by the steering engine of a ship. Its meaning is made clear by the following example.

Suppose that I pick up a pencil. To do this I have to move certain muscles. Only an expert anatomist knows what all these muscles are, and even an anatomist could hardly perform the act by a conscious exertion of the will to contract each muscle concerned in succession. Actually what we will is not to move individual muscles but to pick up the pencil. Once we have determined on this, the motion of the arm and hand proceeds in such a way that we may say that the amount by which the pencil is not yet picked up is decreased at each stage. This part of the action is not in full consciousness.

To perform an action in such a manner, there must be a report to the nervous system, conscious or unconscious, of the amount by which we have failed to pick up the pencil at each instant. The report may be visual, at least in part, but it is more generally kinesthetic, or to use a term now in vogue, proprioceptive. If the proprioceptive sensations are wanting, and we do not replace them by a visual or other substitute, we are unable to perform the act of picking up the pencil, and find ourselves in a state known as ataxia. On the other hand, an excessive feedback is likely to be just as serious a handicap. In the latter case the muscles overshoot the mark and go into an uncontrollable oscillation. This condition, often associated with injury to the cerebellum, is known as purpose tremor.

Here, then, is a significant parallel between the workings of the nervous system and of certain machines. The feedback principle introduces an important new idea in nerve physiology. The central nervous system no longer appears to be a self-contained organ receiving signals from the senses and discharging into the muscles. On the contrary, some of its most characteristic activities are explainable only as circular processes, traveling from the nervous system into the muscles and re-entering the nervous system through the sense organs. This finding seems to mark a step forward in the study of the nervous system as an integrated whole.

EDITOR'S NOTE

The word cybernetics is also the title of a book by Dr. Wiener, just published by John Wiley & Sons, New York. In this article, which is adapted from the book, Dr. Wiener briefly defines cybernetics and discusses some of its possible applications in the pathology of the mind. Dr. Wiener's book may well be the focus of much controversy, both scientific and nonscientific. SCIENTIFIC AMERICAN presents Dr. Wiener's article as an introduction to this discussion.

The new approach represented by cybernetics—an integration of studies which is not strictly biological or strictly physical, but a combination of the two—has already given evidence that it may help to solve many problems in engineering, in physiology and very likely in psychiatry.

This work represents the outcome of a program undertaken jointly several years ago by the writer and Arturo Rosenblueth, then of the Harvard Medical School and now of the National Institute of Cardiology of Mexico. Dr. Rosenblueth is a physiologist; I am a mathematician. For many years Dr. Rosenblueth and I had shared the conviction that the most fruitful areas for the growth of the sciences were those which had been neglected as no-man's lands between the various established fields. Dr. Rosenblueth always insisted that a proper exploration of these blank spaces on the map of science could be made only by a team of scientists, each a specialist but each possessing a thoroughly sound acquaintance with the fields of his fellows.

OUR collaboration began as the result of a wartime project. I had been assigned, with a partner, Julian H. Bigelow, to the problem of working out a fire-control apparatus for anti-aircraft artillery which would be capable of tracking the curving course of a plane and predicting its future position. We soon came to the conclusion that any solution of the problem must depend heavily on the feedback principle, as it operated not only in the apparatus but in the human operators of the gun and of the plane. We approached Dr. Rosenblueth with a specific question concerning oscillations in the nervous system, and his reply, which cited the phenomenon of purpose tremor, confirmed our hypothesis about the importance of feedback in voluntary activity.

The ideas suggested by this discussion led to several joint experiments, one of which was a study of feedback in the muscles of cats. The scope of our investigations steadily widened, and as it did so scientists from widely diverse fields joined our group. Among them were the mathematicians John Von Neumann of the Institute for Advanced Study and Walter Pitts of Massachusetts Institute of Technology; the physiologists Warren McCulloch of

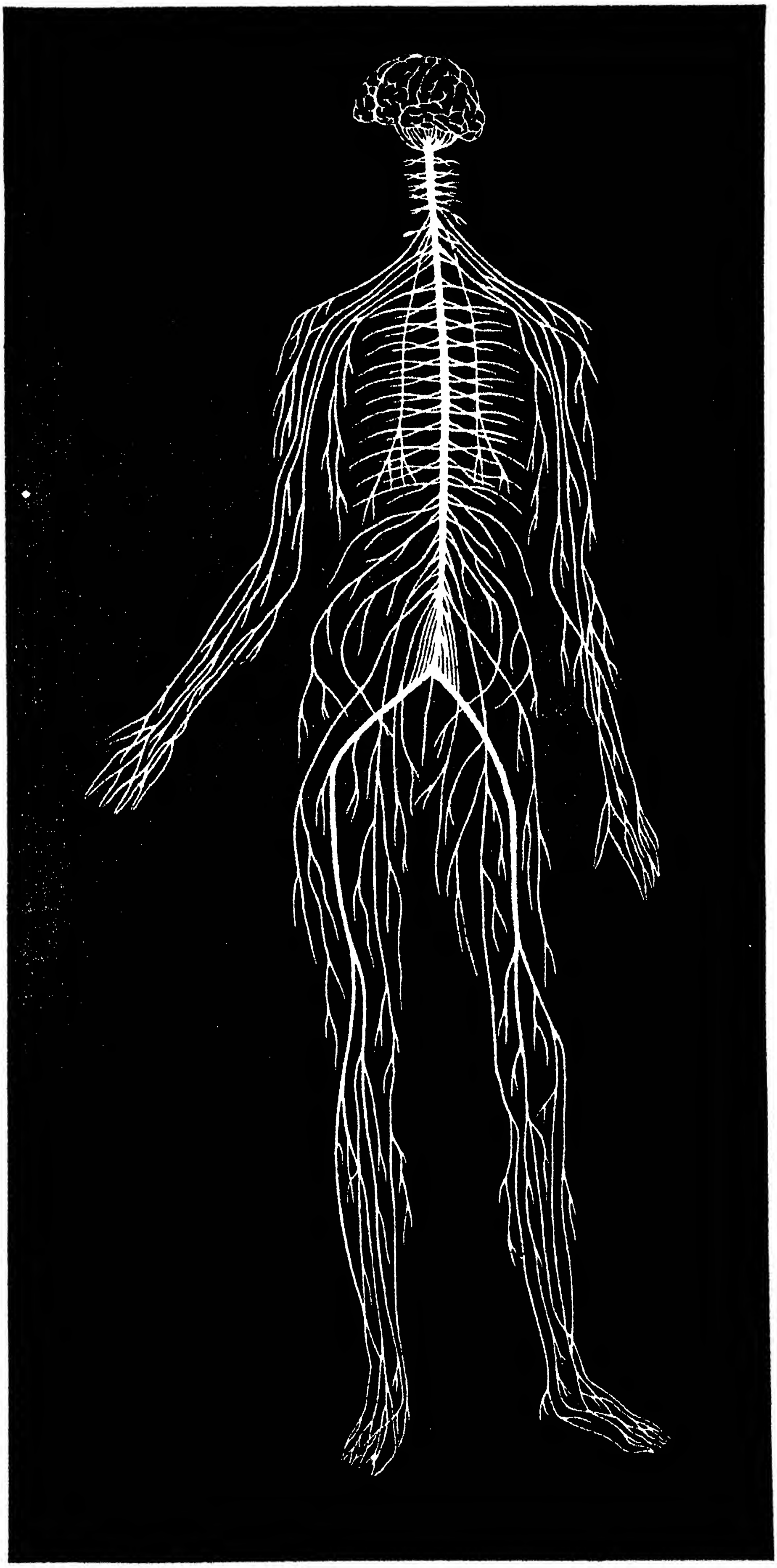
the University of Pennsylvania and Lorente de No of the Rockefeller Institute; the late Kurt Lewin, psychologist, of M. I. T.; the anthropologists Gregory Bateson and Margaret Mead; the economist Oskar Morgenstern of the Institute for Advanced Study; and others in psychology, sociology, engineering, anatomy, neurophysiology, physics, and so on.

The study of cybernetics is likely to have fruitful applications in many fields, from the design of control mechanisms for artificial limbs to the almost complete mechanization of industry. But in our view it encompasses much wider horizons. If the 17th and early 18th centuries were the age of clocks, and the latter 18th and 19th centuries the age of steam engines, the present time is the age of communication and control. There is in electrical engineering a division which is known as the split between the technique of strong currents and the technique of weak currents; it is this split which separates the age just passed from that in which we are living. What distinguishes communication engineering from power engineering is that the main interest of the former is not the economy of energy but the accurate reproduction of a signal.

At every stage of technique since Daedalus, the ability of the artificer to produce a working simulacrum of a living organism has always intrigued people. In the days of magic, there was the bizarre and sinister concept of the Golem, that figure of clay into which the rabbi of Prague breathed life. In Isaac Newton's time the automaton became the clockwork music box. In the 19th century, the automaton was a glorified heat engine, burning a combustible fuel instead of the glycogen of human muscles. The automaton of our day opens doors by means of photocells, or points guns to the place at which a radar beam picks up a hostile airplane, or computes the solution of a differential equation.

Under the influence of the prevailing view in the science of the 19th century, the engineering of the body was naturally considered to be a branch of power engineering. Even today this is the predominant point of view among classically minded, conservative physiologists. But we are now coming to realize that the body is very far from a conservative system, and that the power available to it is much less limited than was formerly believed. We are beginning to see that such important elements as the neurones—the units of the nervous complex of our bodies—do their work under much the same conditions as vacuum tubes, their relatively small power being supplied from outside by the body's circulation, and that the bookkeeping which is most essential to describe their function is not one of energy.

In short, the newer study of automata, whether in the metal or in the flesh, is a branch of communications engineering,

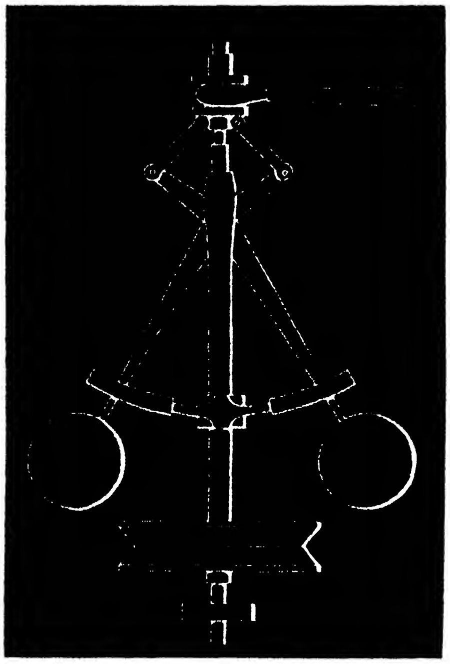


THE NERVOUS SYSTEM, in the cybernetic view, is more than an apparatus for receiving and transmitting signals. It is a circuit in which certain impulses enter muscles and re-enter the nervous system through the senses.

and its cardinal ideas are those of the message, of the amount of disturbance or "noise" (a term taken from the telephone engineer), of the quantity of information to be transmitted, of coding technique, and so on.

This view obviously has implications which affect many branches of science. Let us consider here the application of cybernetics to the problem of mental disorders. The realization that the brain and computing machines have much in common may suggest new and valid approaches to psychopathology, and even to psychiatry.

These begin with perhaps the simplest question of all: how the brain avoids gross blunders or gross miscarriages of activity due to the malfunction of individual parts. Similar questions referring to the computing machine are of great practical importance, for here a chain of operations, each of which covers only a fraction of a millionth of a second, may last a matter of hours or days. It is quite possible for a chain of computational operations to involve a billion separate steps. Under these circumstances, the chance that at least one operation will go amiss is far from negligible, even though the reliability of modern electronic apparatus has exceeded the most sanguine expectations.



GOVERNOR of a steam engine is an example of feedback, one of the most important basic ideas in cybernetics.

In ordinary computational practice by hand or by desk machines, it is the custom to check every step of the computation and, when an error is found, to localize it by a backward process starting from the first point where the error is noted. To do this with a high-speed machine, the check must proceed at the pace of the original machine, or the whole effective order of speed of the machine will conform to that of the slower process of checking.

A much better method of checking, and in fact the one generally used in practice, is to refer every operation simultaneously to two or three separate mechanisms. When two such mechanisms are used, their answers are automatically collated against each other; and if there is a discrepancy, all data are transferred to permanent storage, the machine stops and a signal is sent to the operator that something is wrong. The operator then compares the results, and is guided by them in his search for the malfunctioning part, perhaps a tube which has burned out and needs replacement. If three separate mechanisms are used for each stage, there will practically always be agreement between two of the three mechanisms, and this agreement will give the required result. In this case the collation mechanism accepts the majority report, and the machine need not stop. There is a signal, however, indicating where and how the minority report differs from the majority report. If this occurs at the first moment of discrepancy, the indication of the position of the error may be very precise.

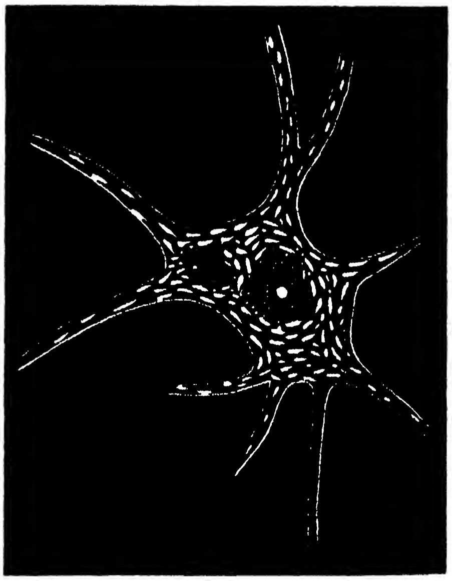
It is conceivable, and not implausible, that at least two of the elements of this process are also represented in the nervous system. It is hardly to be expected that any important message is entrusted for transmission to a single neurone, or that an important operation is entrusted to a single neuronal mechanism. Like the computing machine, the brain probably works on a variant of the famous principle expounded by Lewis Carroll in *The Hunting of the Snark:* "What I tell you three times is true."

It is also improbable that the various channels available for the transfer of information generally go from one end of their course to the other without connecting with one another. It is much more probable that when a message reaches a certain level of the nervous system, it may leave that point and proceed to the next by one or more alternative routes. There may be parts of the nervous system, especially in the cortex, where this interchangeability is much limited or abolished. Still, the principle holds, and it probably holds most clearly for the relatively unspecialized cortical areas which serve the purpose of association and of what we call the higher mental functions.

So far we have been considering errors in performance that are normal, and pathological only in an extended sense. Let us now turn to those that are much more clearly pathological. Psychopathology has been rather a disappointment to the instinctive materialism of the doctors, who have taken the view that every disorder must be accompanied by actual lesions of some specific tissue involved. It is true that specific brain lesions, such as injuries, tumors, clots and the like, may be accompanied by psychic symptoms, and that certain mental diseases, such as paresis, are the sequelae of general bodily disease and show a pathological condition of the brain tissue. But there is no way of identifying the brain of a schizophrenic of one of the strict Kraepelin types, nor of a manic-depressive patient, nor of a paranoiac. These we call functional disorders.

This distinction between functional and organic disorders is illuminated by the consideration of the computing machine. It is not the empty physical structure of the computing machine that corresponds to the brain—to the adult brain, at least—but the combination of this structure with the instructions given it at the beginning of a chain of operations and with all the additional information stored and gained from outside in the course of its operation. This information is stored in some physical form—in the form of memory. But part of it is in the form of circulating memories, with a physical basis that vanishes when the machine is shut down or the brain dies, and part is in the form of long-time memories, which are stored in a way at which we can only guess, but probably also in a form with a physical basis that vanishes at death.

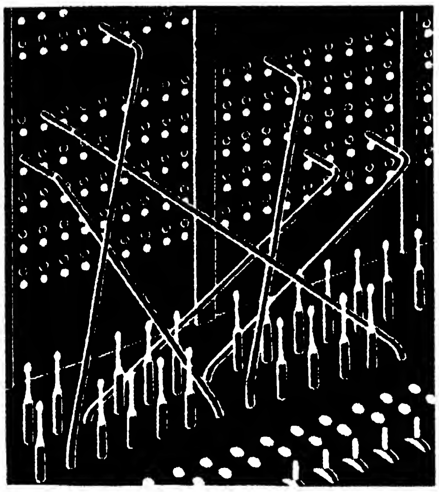
There is therefore nothing surprising in considering the functional mental disorders fundamentally as diseases of memory, of the circulating information kept by the brain in active state and of the long-time permeability of synapses. Even the grosser disorders such as paresis may produce a large part of their effects not so much by the destruction of tissue which they involve and the alteration of synaptic thresholds as by the secondary disturbances of traffic, the overload of what remains of the nervous system and the rerouting of messages which must follow such primary injuries.



NERVE CELL performs functions in much the same situation as a vacuum tube, obtaining power from outside.

In a system containing a large number

of neurones, circular processes can hardly be stable for long periods of time. Either they run their course, dissipate themselves and die out, as in the case of memories belonging to the specious present, or they embrace more and more neurones in their system, until they occupy an inordinate part of the neurone pool. This is what we should expect to be the case in the malignant worry that accompanies anxiety neuroses. In such a case, it is possible that the patient simply does not have the room —*i.e.*, a sufficient number of neurones—



TELEPHONE EXCHANGE, when it is overloaded, has breakdowns rather similar to the kind in human beings.

to carry out his normal processes of thought. Under such conditions, there may be less going on in the brain to occupy the neurones not yet affected, so that they are all the more readily involved in the expanding process. Furthermore, the permanent memory becomes more and more deeply involved, and the pathological process which began at the level of the circulating memories may repeat itself in a more intractable form at the level of the permanent memories. Thus what started as a relatively trivial and accidental disturbance of stability may build itself up into a process totally destructive to the normal mental life.

Pathological processes of a somewhat similar nature are not unknown in the case of mechanical or electrical computing machines. A tooth of a wheel may slip under such conditions that no tooth with which it engages can pull it back into its normal relations, or a high-speed electrical computing machine may go into a circular process that seems impossible to stop.

HOW do we deal with these accidents in the case of the machine? We first try to clear the machine of all information, in the hope that when it starts again with different data the difficulty will not recur. If this fails and the difficulty is inaccessible to the clearing mechanism, we shake the machine or, if it is electrical, subject it to an abnormally large electrical impulse in the hope that we may jolt the inaccessible part into a position where the false cycle of its activities will be interrupted. If even this fails, we may disconnect an erring part of the apparatus, for it is possible that what remains may be adequate for our purpose.

In the case of the brain, there is no normal process, except death, that can clear it of all past impressions. Of the normal non-fatal processes, sleep comes closest to clearing the brain. How often we find that the best way to handle a complicated worry or an intellectual muddle is to sleep on it! Sleep, however, does not clear away the deeper memories, nor indeed is a malignant state of worry compatible with adequate sleep.

Thus we are often forced to resort to more violent types of intervention in the memory cycle. The most violent of these involve surgery on the brain, leaving behind permanent damage, mutilation and the abridgement of the powers of the victim, for the mammalian central nervous system seems to possess no power of regeneration. The principal type of surgical intervention that has been practiced is known as prefrontal lobotomy, or leucotomy. It consists in the removal or isolation of a portion of the prefrontal lobe of the cortex. It is currently having a certain vogue, probably not unconnected with the fact that it makes the custodial care of many patients easier. (Let me remark in passing that killing them makes their custodial care still easier.) Prefrontal lobotomy does seem to have a genuine effect on malignant worry, not by bringing the patient nearer to a solution of his problem, but by damaging or destroying the capacity for maintained worry, known in the terminology of another profession as the conscience. It appears to impair the circulating memory, *i.e.*, the ability to keep in mind a situation not actually presented.

The various forms of shock treatment—electric, insulin, metrazol—are less drastic methods of doing a very similar thing. They do not destroy brain tissue, or at least are not intended to destroy it, but they do have a decidedly damaging effect on the memory. In so far as the shock treatment affects recent disordered memories, which are probably scarcely worth preserving anyhow, it has something to recommend it as against lobotomy, but it is sometimes followed by deleterious effects on the permanent memory and the personality. As it is used at present, it is another violent, imperfectly understood, imperfectly controlled method to interrupt a mental vicious circle.

In long-established cases of mental disorder, the permanent memory is as badly deranged as the circulating memory. We do not seem to possess any purely pharmaceutical or surgical weapon for intervening selectively in the permanent memory. This is where psychoanalysis and the other psychotherapeutic measures come in.

Whether psychoanalysis is taken in the orthodox Freudian sense or in the modified senses of Jung and of Adler, or whether the psychotherapy is not strictly psychoanalytic at all, the treatment is clearly based on the concept that the stored information of the mind lies on many levels of accessibility. The effect and accessibility of this stored information are vitally conditioned by affective experiences that we cannot always uncover by introspection. The technique of the psychoanalyst consists in a series of means to discover and interpret these hidden memories, to make the patient accept them for what they are, and thus to modify, if not their content, at least the affective tone they carry, and make them less harmful.

All this is perfectly consistent with the cybernetic point of view. Our theory perhaps explains, too, why there are circum-

AUTOMATON of the 15th century was one of a long series of attempts to assign human functions to machinery.

stances in which a joint use of shock treatment and psychotherapy is indicated, combining a physical or pharmacological therapy for the malignant reverberations in the nervous system and a psychological therapy for the damaging long-time memories which might re-establish the vicious circle broken up by the shock treatments.

We have already mentioned the traffic problem of the nervous system. It has been noted by many writers that each form of organization has an upper limit of size beyond which it will not function. Thus insect organization is limited by the length of tubing over which the spiracle method of bringing air by diffusion directly to the

breathing tissues will function; a land animal cannot be so big that the legs or other portions in contact with the ground will be crushed by its weight (*see page 52*), and so on. The same sort of thing is observed in engineering structures. Skyscrapers are limited in size by the fact that when they exceed a certain height, the elevator space needed for the upper stories consumes an excessive part of the cross section of the lower floors. Beyond a certain span, the best possible suspension bridge will collapse under its own weight. Similarly, the size of a single telephone exchange is limited.

In a telephone system, the important limiting factor is the fraction of the time during which a subscriber will find it impossible to put a call through. A 90 per cent chance of completing calls is probably good enough to permit business to be carried on with reasonable facility. A success of 75 per cent is annoying but will permit business to be carried on after a fashion; if half the calls are not completed, subscribers will begin to ask to have their telephones taken out. Now, these represent all-over figures. If the calls go through a number of distinct stages of switching, and the probability of failure is independent and equal for each stage, in order to get a high probability of final success the probability of success at each stage must be higher than the final one. Thus to obtain a 75 per cent chance for the completion of the call after five stages, we must have about 95 per cent chance of success at each stage. The more stages there are, the more rapidly the service becomes extremely bad when a critical level of failure for the individual call is exceeded, and extremely good when this critical level of failure is not quite reached. Thus a switching service involving many stages and designed for a certain level of failure shows no obvious signs of failure until the traffic comes up to the edge of the critical point, when it goes completely to pieces and we have a catastrophic traffic jam.

So man, with the best developed nervous system of all the animals, probably involving the longest chains of effectively operated neurones, is likely to perform a complicated type of behavior efficiently very close to the edge of an overload, when he will give way in a serious and catastrophic manner. This overload may take place in several ways: by an excess in the amount of traffic to be carried; by a physical removal of channels for the carrying of traffic; or by the excessive occupation of such channels by undesirable systems of traffic, such as circulating memories that have accumulated to the extent of becoming pathological worries. In all these cases, a point is reached—quite suddenly—when the normal traffic does not have space enough allotted to it, and we have a form of mental breakdown, very possibly amounting to insanity.

This will first affect the faculties or operations involving the longest chains of neurones. There is appreciable evidence, of various kinds, that these are precisely the processes recognized as the highest in our ordinary scale of valuation.

If we compare the human brain with that of a lower mammal, we find that it is much more convoluted. The relative thickness of the gray matter is much the same, but it is spread over a far more involved system of grooves and ridges. The effect of this is to increase the amount of gray matter at the expense of the amount of white matter. Within a ridge, this decrease of the white matter is largely a decrease in length rather than in number of fibers, as the opposing folds are nearer together than the same areas would be on a smooth-surfaced brain of the same size. On the other hand, when it comes to the connectors between different ridges, the distance they have to run is increased by the convolution of the brain.

Thus the human brain would seem to be fairly efficient in the matter of the short-distance connectors, but defective in the matter of long-distance trunk lines. This means that in the case of a traffic jam, the processes involving parts of the brain quite remote from one another should suffer first. That is, processes involving several centers, a number of different motor processes and a considerable number of association areas should be among the least stable in cases of insanity. These are precisely the processes which we should normally class as higher, thereby confirming our theory, as experience does also, that the higher processes deteriorate first in insanity.

THE phenomena of handedness and of hemispheric dominance suggest other interesting speculations. Right-handedness, as is well known, is generally associated with left-brainedness, and left-handedness with right-brainedness. The dominant hemisphere has the lion's share of the higher cerebral functions. In the adult, the effect of an extensive injury in the secondary hemisphere is far less serious than the effect of a similar injury in the dominant hemisphere. At a relatively early stage in his career, Louis Pasteur suffered a cerebral hemorrhage on the right side which left him with a moderate degree of one-sided paralysis. When he died, his brain was examined and the damage to its right side was found to be so extensive that it has been said that after his injury "he had only half a brain." Nevertheless, after this injury he did some of his best work. A similar injury to the left side of the brain in a right-handed adult would almost certainly have been fatal; at the least it would have reduced the patient to an animal condition.

In the first six months of life, an extensive injury to the dominant hemisphere may compel the normally secondary hemisphere to take its place, so that the patient appears far more nearly normal than he would have been had the injury occurred at a later stage. This is quite in accordance with the great flexibility shown by the nervous system in the early weeks of life. It is possible that, short of very serious injuries, handedness is reasonably flexible in the very young child. Long before the child is of school age, however, the natural handedness and cerebral dominance are established for life. Many people have changed the handedness of their children by education, though of course they could not change its physiological basis in hemispheric dominance. These hemispheric changelings often become stutterers and develop other defects of speech, reading and writing.

We now see at least one possible explanation for this phenomenon. With the education of the secondary hand, there has been a partial education of that part of the secondary hemisphere which deals with skilled motions such as writing. Since these motions are carried out in the closest possible association with reading, and with speech and other activities which are inseparably connected with the dominant hemisphere, the neurone chains involved in these processes must cross over from hemisphere to hemisphere, and in any complex activity they must do this again and again. But the direct connectors between the hemispheres in a brain as large as that of man are so few in number that they are of very little help. Consequently the interhemispheric traffic must go by roundabout routes through the brain stem. We know little about these routes, but they are certainly long, scanty and subject to interruption. As a consequence, the processes associated with speech and writing are very likely to be involved in a traffic jam, and stuttering is the most natural thing in the world.

The human brain is probably too large already to use in an efficient manner all the facilities which seem to be present. In a cat, the destruction of the dominant hemisphere seems to produce relatively less damage than in man, while the destruction of the secondary hemisphere probably produces more damage. At any rate, the apportionment of function in the two hemispheres is more nearly equal. In man, the gain achieved by the increase in the size and complexity of the brain is partly nullified by the fact that less of the organ can be used effectively at one time.

It is interesting to reflect that we may be facing one of those limitations of nature in which highly specialized organs reach a level of declining efficiency and ultimately lead to the extinction of the species. The human brain may be as far along on its road to destructive specialization as the great nose horns of the last of the titanotheres.

Norbert Wiener is professor of mathematics at Massachusetts Institute of Technology.

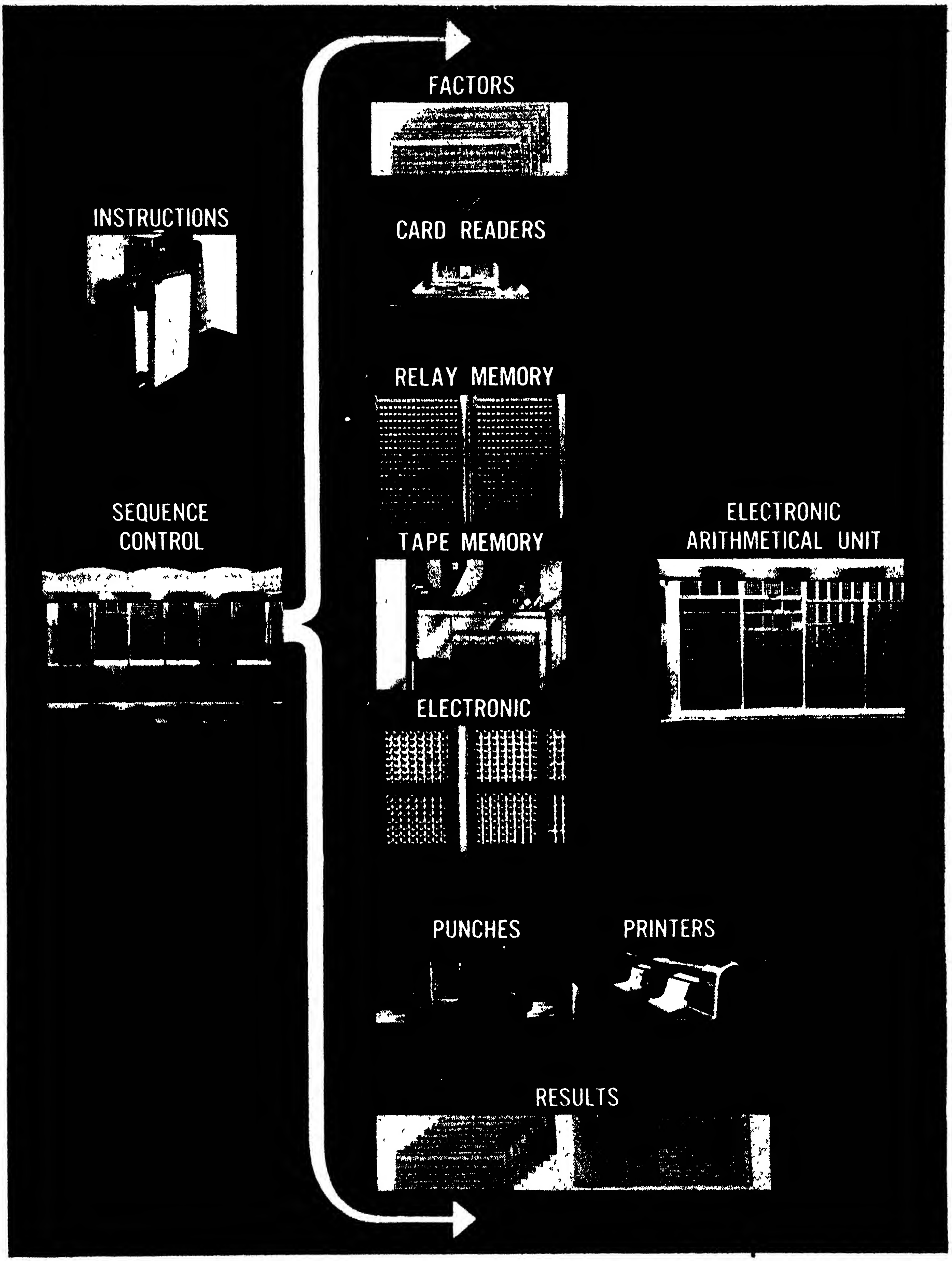


DIAGRAM OF CALCULATOR, in this case the Selective Sequence Electronic Calculator built by the International Business Machines Corporation, provides another cybernetic comparison. Physical structure of the machine is not analogous to the brain. The structure plus instructions and stored memories is analogous. The machine has electronic and relay circuits for temporary memory, punched cards for permanent memory.

SPRUCE, BALSAM AND BIRCH

Three trees that live together in the woods of the North are examples of both beauty and utility. One in a series of articles about trees

by Donald Culross Peattie

THE most beautiful approach to the North American Continent from Europe is up the St. Lawrence to Quebec. The grandeur of this estuary, the greatest, save the Amazon's, in all the world, the storm of gannets from the bird rocks, the white cliffs of the Gaspé Peninsula, would be enough to make it incomparable. But most impressive of all is the vast coniferous forest, so dark a green that it looks almost black, stretching from the north shore away and away to the horizon and beyond, for hundreds of impenetrable miles, to the Arctic limit of trees. In this forest are set the little villages of French Canada, the inevitable white steeple and gold cross gleaming against the evergreens and the raw, elemental blue of the sky. Each of these villages seems, from the deck of the ship, a collection of toy houses and churches pressed closely by Christmas trees. And of all the conifers there, the fairest is the White Spruce, the handsomest of its family.

It was in the basin of the St. Lawrence, indeed, that the White Spruce was first seen by Jacques Cartier when in the autumn of 1535 he sailed up the Saguenay River. "From the day of the 18th to the 28th of this month we have sailed up this river without losing an hour nor a day, during which time we have seen and found as beautiful a country and lands and views as one could wish for, level as aforementioned, and the finest trees in the world, to wit oaks, elms, walnuts, cedars, spruces, ash trees, willows and wild vines."

In youth the White Spruce forms a fine spirelike top, with a central stem straight as a mast, ending at the acute, symmetrical tip; the lowest arms sweep benignly down almost to earth, then turn up at the twig, like fingers lifted in a gesture of easy grace. The foliage tends to curl, no matter from what side of the branch it may spring, toward the top of the twig, and so appears combed up and out. When crushed, it gives out a pungent, almost skunky odor.

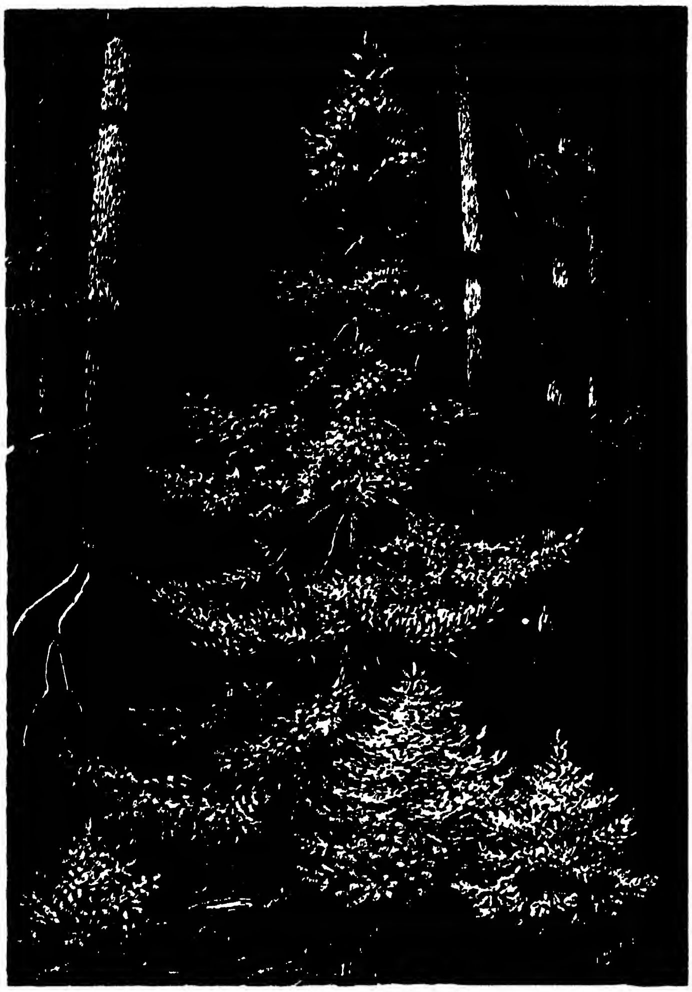
Banks of streams and lakes, and borders of swamps, are the habitat of this fine tree; it seeks out ocean cliffs along the coast of Maine, where the salt spray of the Atlantic burns the needles on the windward side, and the sea winds sculpture it into fantastic forms. On the eastern slopes of the Canadian Rockies it attains its greatest height—sometimes 150 feet, with a trunk 3 or 4 feet thick. It reaches almost to the Arctic Ocean in scattered groves, and every one of the rivers of the Mackenzie and Yukon provinces is choked with the naturally fallen logs of White Spruce, while its driftwood is piled, whitening, on their banks and shoals.

In Canada, especially the western provinces, White Spruce is often a fine lumber tree, used for interior finish. Its greatest use, though, is in the making of paper pulp; the least noted of all lumber industries, pulping is, since the disappearance of the great stands of virgin White and Red Pine, the most important forest industry of eastern Canada. Pulp manufacture requires an abundant tree with very soft fibers. White Spruce answers exactly to this description, and so tremendous has become the drain on our pulpwoods that many great newspapers in the U. S. own their own Spruce forests in Canada, and by operating on successive tracts over a sufficiently great area they hope that this fast-growing Spruce will furnish them a self-renewing crop in perpetuity. In vain have American lumbermen sought to raise a tariff wall against Canadian Spruce; for once the lumbermen's powerful lobbies have met their equals in the press, and Canadian pulp still comes in as a precious raw material, just like rubber, silk and coffee.

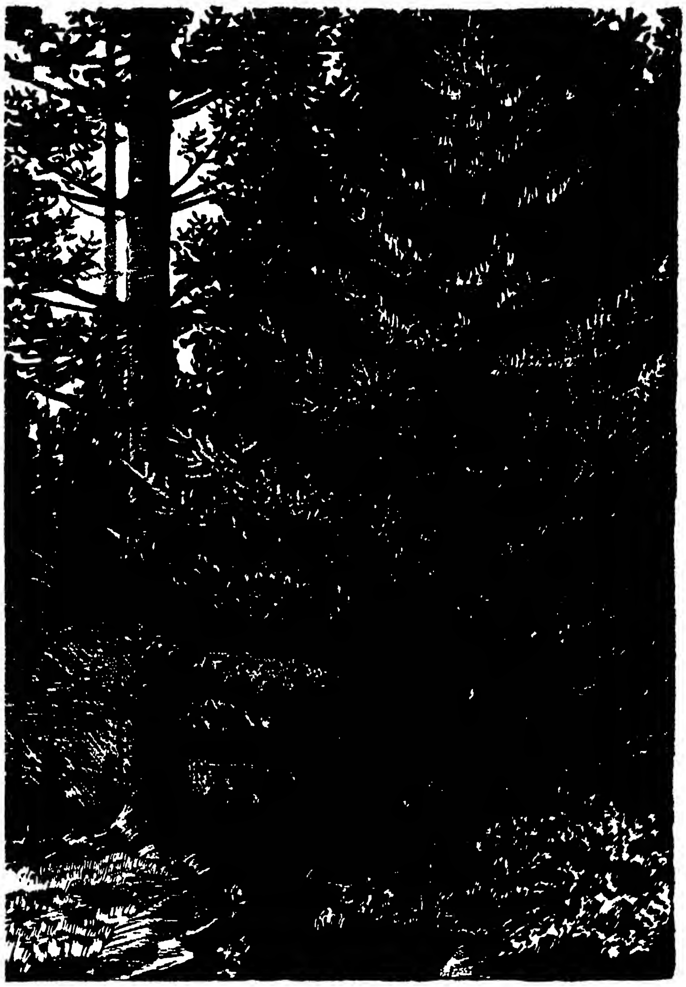
In the making of pulp, the fiber is torn apart by great grindstones kept cool by water, until the log is reduced to a dirty slush; or else the pure cellulose is freed by dissolving out the gummy lignins with sulfite or soda. To this sludge are added all the fillers, such as rosin, alum, and gelatin for sizing, clays to give body and polish to coated papers, and dyes for colored papers. Then the pulp is drained and mechanically dried, in principle as one dries clothes with wringer or mangle, but by a series of machines that are a marvel of inventive skill. There emerges at last in the great mills a continuous flowing sheet of paper which never stops, year in, year out, unless the paper breaks. To produce a ton of newsprint requires one cord of wood, 2,800 tons of water, nearly 2,000 kilowatt hours of electrical energy or 100 horsepower for 24 hours, and a capital up to $50,000 per ton of daily output.

CANOE BIRCH often dwells with conifers. It grows readily on cutover land, replacing Pines and the Spruces.

THE BALSAM, frequent associate of the Spruce, is fortunately of little practical use to the lumberman. But except with the old-time logger, who had no use for Balsam save to make himself a natural sweet-smelling mattress laid on a springy frame of Spruce boughs, this is the most popular of all the trees in the great North Woods. To anyone whose childhood summers were spent there, the fragrance of Balsam needles is the finest in nature. Merely to remember it is to recall lake waters, or the high swell of the northern Appalachians, or the grandeur of the St. Lawrence Gulf. It brings back the smell of wild raspberries in the sunlit clearing, the white-throated sparrow's song, the flight of the canoe from the paddle stroke. For Balsam loves the rocky



WHITE SPRUCE is a tree of great commercial value because it is used to make paper pulp. In the foreground is a young Spruce; to the rear are mature specimens.



BALSAM is best known as a Christmas tree and for its fine scent. Its resin yields Canada balsam, used to seal microscope slides and in the manufacture of varnish.

soil close to water, where its familiar is often the Canoe Birch. At the edge of any sparkling lake, in the great glaciated province of eastern Canada and the northern U. S., these two grow in felicitous contrast, the Balsam with its gleaming but motionless evergreen foliage and its straight stem and precise whorls of branches, and the white-barked, leaning and gracile Birch with its showers of pale green, restless foliage.

For success in the eternal forest battle for survival, Balsam depends upon its adaptability, the speed of its growth, its fertility. The seeds are many and highly viable, but the grouse and the red squirrels and the pine mice eat them, just as moose and deer browse on the foliage. Balsam is also a danger to itself because of the resin blisters under its bark, which, in forest fires, ignite so that the whole tree is soon a blazing torch.

These resin blisters yield what is called Canada balsam, a sort of turpentine employed in the manufacture of varnish. It is familiar to all advanced students in the biological sciences as a transparent fixative for mounting and preserving specimens under the microscope. It not only seals the cover glass to the glass slide, but is a matrix for the specimen to hold and preserve it from drying or decay. Balsam, moreover, has the fortunate property of refracting light exactly as glass does so that the balsam matrix, the cover glass, and the microscope lenses become one optical system with the same refractive index.

One of the odd things about the lovely aroma of Balsam branches is that many people who live with it constantly can no longer smell it. The city visitor has the sharpest pleasure in it. If he collects the needles to make a balsam pillow, he takes the odor home with him, and for a time he can detect it. But presently he may fail to do so, though the smell is there for others, and he may not notice it again until the fresh Christmas tree is brought into his house. Balsams are the ideal Christmas trees—fragrant beyond all others, with long lower branches and thick, spirelike tops. The needles do not drop like those of the Spruce, even after a month without water, nor do they stab the hand when one is decorating the tree, since they are not tipped with prickles.

The Christmas tree industry is now a big, though a seasonal, business. On forest land the proper selection of little trees will merely result in betterment of the stand. On farms and estates the raising of trees, from seedlings supplied free or at cost by state forestry nurseries, offers, on land not otherwise profitable, possibilities that were dramatized by the highly successful Hyde Park plantations of Franklin D. Roosevelt. Yet from time to time some overzealous moralist decides that we are depleting our forests by cutting millions of young Christmas trees every year for a momentary pleasure, thus robbing ourselves of tens of millions of feet of lumber. But out of every ten young trees in the forest, nine are destined to lose out and die. No harm, but only good, can follow from the proper cutting of young Christmas trees. And the destiny of Balsam, most beautiful of them all, would otherwise too often be excelsior, or boards for packing cases, or newsprint.

WHEREVER it grows the Canoe Birch enjoys the company of conifers and the presence of water, it seeks out rushing streams and cold, clear lakes. Sometimes it is found in swamps and boggy meadows and, if it must leave the neighborhood of moisture, it likes deep, rocky woods with cool soil. Fortunately it is light-tolerant in youth, so it comes up readily on cutover land, and has replaced the White Pine and the Spruces over large

WHITE BARK is the distinctive feature of the Canoe Birch. Pulled away from the trunk in thin sheets, it served the Indians as a covering for canoes. Canoe Birch bark peels more readily than the bark of White Birch.

parts of New England, eastern Canada and the northern peninsula of Michigan.

Thus has Canoe Birch gained ground within historic times, and if there are fewer big specimens than there were, time may take care of that. For the Birch, where it is found near habitations, is usually spared for its beauty. As a result it is now one of the best-loved trees of the New England landscape, and when we remember a scene there we see Birches in it—gleaming white trunks, houses and churches painted a clean white, and pure country snow stretching over valley and hill.

In its great range, the Canoe Birch takes many forms; on the mountains of New England it is sometimes a dwarfed and bushy plant, while in the rich forests it grows 60 feet high; in the virgin woods it probably attained twice that height, if old reports can be trusted. Though a botanist may quibble over differences in a leaf, all the botanical varieties add up to the same thing—a tree of incomparable grace and loveliness, identifiable at a glance by its shining scaly bark. The only possible confusion would be with the much-cultivated European White Birch, which one knows by its more pendulous "weeping" branches and by the bark that is much closer and tighter than the more readily peeling bark of our Canoe Birch.

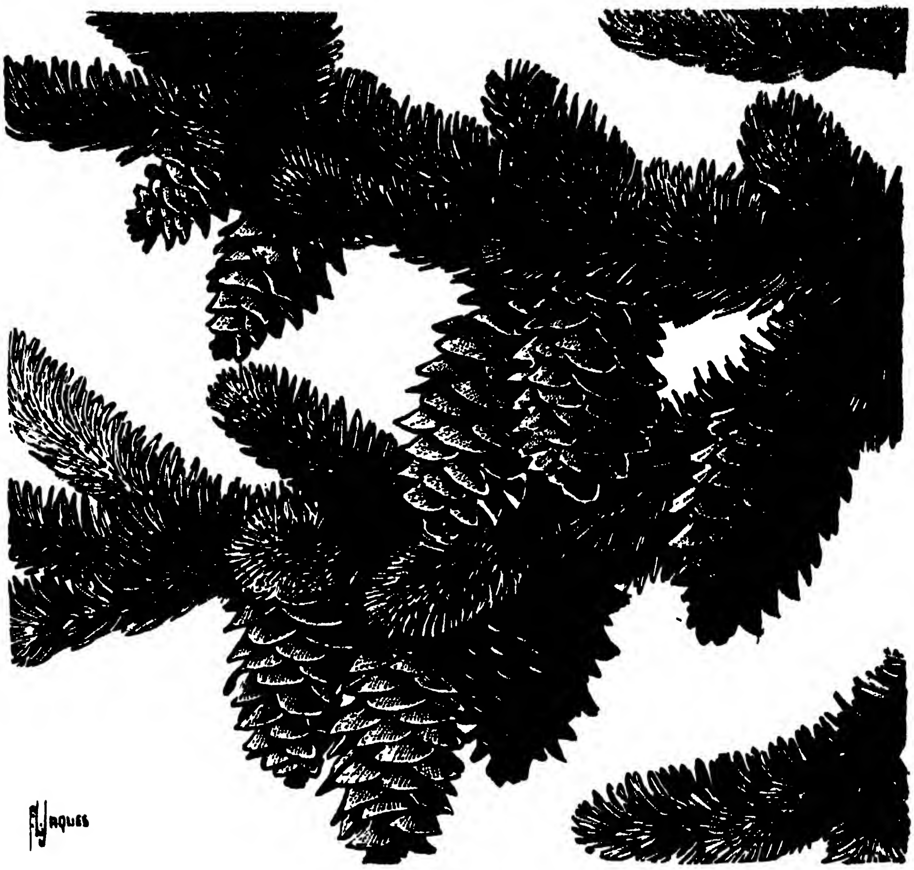
To an American of an older generation, there was no more happy experience than the moment when on his first visit to the North Woods he stepped into a Birch-bark canoe weighing perhaps no more than 50 pounds, but strong enough to carry 20 times as much. At the first stroke of the paddle it shot out over the water like a bird. The Indians taught the early settlers how to strip the bark from the Birch, separate it into thin sheets, and sew them with long, slender roots of Tamarack for thread. The bark was then stretched and tied over the frame—commonly made of northern White Cedar or Arbor Vitae—while the holes in the bark and the partings at the seams were caulked with resin of Pine or Balsam or Balm-of-Gilead. Other barks and skins were often used for canoes, but of them all Birch is the most renowned—the lightest and most beautiful, and yet so strong that the Indian trusted his life to it when he shot the rock-studded rapids.

Birchwood furnished the Indian with snowshoe frames. The bark served him, sometimes, as a covering for the tepee or lodge. Rolled into a spill, it constituted a taper or a punk stick to keep away mosquitoes. It made good paper for kindling a fire started first in punkwood of rotten Yellow Birch. A moose-calling horn of Birch bark was carried by all the Indian hunters in the North Woods—a straight tube about 15 inches long and 3 or 4 wide at the mouth, tied about with strips of more Birch bark.

The inner bark of Canoe Birch is a favorite of the beaver, when Aspen is not present. Deer and moose browse the twigs in winter; the buds are eaten by grouse. Sugar can be tapped from this Birch, as from the Maple. Thus to each inhabitant of the North Woods, man or beast, Birch is life-sustaining. Though the lumbermen in the days of the White Pine had little use for the wood itself, they were glad enough to stuff Birch bark, as a waterproof inner lining, under the Cedar shingles of their bunkhouses made of Yellow Birch logs.

And, to the delight of children, the peeling bark has long been a woodland paper. But do not strip it from the living trees, for once the beautiful outer bark is pulled away, it never grows again. Instead, ugly black rings—which you see all too often—take its place. There is always a fallen Birch log from which you can tear sheets. For the Birch is, despite its strength, not a long-lived tree, and once it is dead, decay is swift, and the white trunk soon topples into the old forest loam. Then the mosses gather on its fallen limbs, a green halo that shows how life carries on, though its forms forever change.

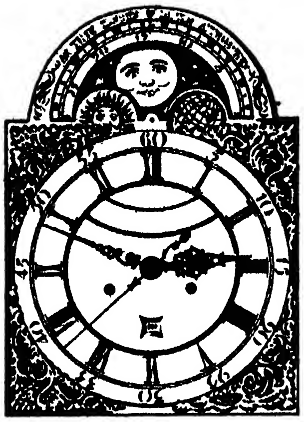
Donald Culross Peattie is a botanist and the author of books and articles about botany and other subjects.



SPRUCE CONES hang downward from the branches of the tree that bears them. Their scales are relatively thick and flare outward from the stem.

BALSAM CONES, in contradistinction to Spruce cones, stand upright on the Balsam branch. Their scales are thin and folded close to one another.

SCIENCE AND



First Atomic Power Plant

WITHIN the next few months, the General Electric Company will begin building for the U. S. Atomic Energy Commission the first atomic plant specifically designed for the production of power. The new plant, to be located on a 4,500-acre site nine miles from the famous New York resort of Saratoga Springs, may be completed in three years. Its cost and projected output have not been disclosed.

The G. E. plant is a third step in the AEC power development program Two other power-generating piles are currently under construction, one at Brookhaven National Laboratory on Long Island and the other at the Argonne National Laboratory in Chicago. The Brookhaven plant will generate only enough power to run part of its auxiliaries. The Argonne pile will be used primarily for testing power plant components. The G. E. installation, combining a high-temperature pile with a steam-turbine generator, is to function as an actual power plant.

Tar Sands

A SUBSTANTIAL part of the world's potential petroleum reserves is locked up in tar sands, an asphaltlike mixture which is widely distributed but from which the oil is not easily extracted. Because much of the world supply of these sands is concentrated in a single gargantuan deposit near the Athabaska River north of Edmonton, Alberta, the Canadian Government and the Research Council of Alberta for several years have sought to develop an economical process for extracting the oil. The Council now reports that progress at last is being made. It has had encouraging results with two processes: 1) distillation; 2) flooding the sand beds with hot water. The hot water method seems somewhat more promising, for it can be utilized on the site and avoids the expense of mining and transporting the sands. There are several problems still to be worked out, however: the sands must be heated to more than 100 degrees Fahrenheit to obtain a worthwhile flow of oil; separation of the oil and water afterward is difficult; the oil has a high sulfur content. These problems will be studied in a pilot plant currently being erected by the Canadian Government at Bitumount on the Athabaska River.

If oil can be extracted economically from the Athabaska sands, Alberta may rival East Texas as a petroleum producer. These sands are believed to contain more than 200 billion barrels of oil--more than the entire remaining reserves in crude oil pools in North and South America. Besides the sands, Alberta has extensive oil resources in pools. Turner Valley in western Alberta, Canada's sole important oil-producing area up to now, has passed its peak, but several new Alberta fields—Leduc, Bantry, Lloydminster-Lone Rock and others--are being opened up. Still others are certain to be found, since evidences of oil are widespread and the province is known to be underlaid with a northern extension of the oil-bearing geological formations of our Great Plains states.

Compton Replaces Bush

AFTER two years of service, Vannevar Bush has retired as chairman of the nation's central military research agency: the Research and Development Board of the Armed Forces. His place is being taken by another outstanding scientist-administrator, President Karl T. Compton of the Massachusetts Institute of Technology.

Bush will return to his post as head of the Carnegie Institution of Washington. He has spent nearly all of the past six years in government service; he directed the Office of Scientific Research and Development throughout the war and was the first chairman of the Research and Development Board. For a few months he will remain on the board as a part-time deputy chairman. Dr. Compton, who also played a leading role in the wartime OSRD, will give his new job full time. His job at M.I.T., which he had held since 1930, will be taken by Dr. James Rhyne Killian, Jr.

Loyalty Problem Committee

A NEW Scientists' Committee on Loyalty Problems has been formed by the Federation of American Scientists under the sponsorship of nearly 50 distinguished figures from the ranks of natural science. The Committee, made up of FAS members at Princeton University and at Brookhaven National Laboratory, will carry on a broad program of activities in defense of scientists' civil liberties, from furnishing advice to scientists with clearance problems to educating the public on the connection between civil rights and scientific progress.

FAS has had an active Committee on Secrecy and Clearance for more than a year. Headed by S. H. Bauer, chairman of the Cornell physics department, and drawn from the FAS membership at Cornell, it has served primarily as an agency for collecting information on clearance procedures and on the difficulties of individual scientists. The new, broader Committee will employ the Cornell group, which will continue a separate existence, for the present at least, as an information-gathering arm.

The new Committee declares that secrecy and loyalty will continue to be problems "until we solve the problem of lasting peace," but "the application of clearance procedures used to date has caused some grave and wholly unnecessary injustices to many scientists."

The Committee, with headquarters in Princeton, is temporarily headed by W. A. Higinbotham of Brookhaven. Its 16 members include Lyman Spitzer, Jr., the Princeton astronomer, and H. D. Smyth, author of the famous *Atomic Energy for Military Purposes*. Among the sponsors are A. J. Carlson of the University of Chicago; E. P. Wigner of Princeton; V. F. Weiskopf of the Massachusetts Institute of Technology; Albert Einstein, and Nobelists James Franck, John H. Northrop and H. C. Urey.

Atomic Debate

LAST spring the United Nations Atomic Energy Commission, over the objections of Russia and the Ukraine, endorsed the U. S. atomic energy control plan and recommended that the UN General Assembly authorize a suspension of negotiations until the U.S.S.R. was ready to accept the U. S. plan. The Commission's report raised a storm in the Assembly, which has been meeting in Paris since September 15. A sizable bloc of smaller powers, led by Australia, New Zealand and Syria, charges that approval of the report will put the atomic control problem in "indefinite cold storage." This the small-power bloc is determined to prevent. At the present writing, it appears that the bloc will succeed.

During the first fortnight of the session, the smaller powers forced withdrawal of a Canadian resolution, which had U. S. and British backing, endorsing the Commission report. Instead, the Assembly created an 11-nation subcommittee to explore the possibilities of East-West compromise on the atom. The subcommittee came up with a proposal that the atomic problem be referred to the Big Five plus Canada for study until next year's Assembly meeting. In a single day, seven of the smaller powers delivered strongly worded attacks on the subcommittee pro-

posal. Then the smaller powers put through a directive instructing the Atomic Energy Commission also to resume work on the atomic problem.

Book Exchange

ONE of the most urgent tasks of overseas reconstruction is the restoration of war-ruined libraries. For two years after the end of hostilities, the burden of refilling the shelves of libraries abroad was carried by an emergency organization, the American Book Center for War Devastated Libraries, Inc., which shipped several million pieces of library material overseas. The reconstruction task is now to be continued through an ingenious exchange plan which will be operated by a new non-profit agency, the United States Book Exchange.

The plan will permit foreign libraries to trade books, periodicals and other materials published in their countries for American library duplicates. The program promises American libraries a steady, inexpensive supply of foreign publications. The Book Exchange, in which all leading U. S. library associations are participating, will prepare lists of publications available for exchange here and abroad; the foreign lists will be circulated to American libraries, and the American lists to foreign centers. Libraries will order from these lists.

Until normal conditions are restored, libraries in war-ruined areas will receive two items for each one furnished and will be permitted to overdraw their accounts. Handling charges will be collected only from "hard-currency" countries, the resulting deficits will be made up by private American funds. Eventually, trade will be on a one-for-one basis and the costs of the program will be met wholly out of a small charge for each item a library receives.

The Book Exchange, whose operating executive is Alice D. Ball, will work through both individual foreign libraries and the national book exchanges which are being set up as part of a separate UNESCO program for facilitating the purchase of books in hard-currency countries by libraries in soft-currency areas. The Exchange will also transmit gift book collections.

WHO in China

THE best-known activity of the World Health Organization in the field of tuberculosis is its program, undertaken jointly with the International Children's Emergency Fund, for protecting all uninfected European children by BCG immunization. But WHO is also waging war against the white plague in other areas. In China, for example, WHO is establishing a series of demonstration tuberculosis control centers in cooperation with Chinese health authorities. Five are already in operation, at Canton, Nanking, Peiping, Shanghai and Tientsin.

The Canton center, opened in June, is typical. Its staff, directed by a WHO medical officer, Dr. I. M. Lourie, is largely Chinese. The center, equipped with two X-ray microfilm units furnished by the American Red Cross and UNRRA, examines about 1,000 persons a week. The main treatment is rest—and much is done daily in arranging for it in the chaos of contemporary China. Lung collapse and surgery also are employed. BCG immunization, already in use at the other clinics, will be instituted at Canton early next year. All treatment is free to those who cannot afford to pay. The clinic's activities also include a teaching program for both technicians and doctors. Fourteen additional demonstration tuberculosis clinics are to be set up in other Chinese cities, making 19 demonstration clinics altogether when WHO's Chinese program is completed.

Powdered Milk

SINCE the end of the war, UNRRA, the International Children's Emergency Fund and other relief agencies have shipped several hundred million pounds of powdered milk to Europe. At first, dried milk met resistance from its intended users. Now it is effecting an important change in European food technology.

In many parts of Europe, pasteurization and refrigeration equipment have always been scarce. Hence milk could not be moved from surplus to deficiency areas, nor held over from surplus to deficiency months; what was not consumed on the spot or converted to cheese was spoiled. Three and a half years of experience, however, have shown that dehydration offers a practical solution. Equipment for drying milk is relatively inexpensive and simple to operate, and powdered milk (whole or skimmed) is as nutritious as the product from which it is made. Consequently, nearly all European countries, either on their own or with help from agencies like the Children's Fund, are making plans to establish local milk-drying industries to provide the first year-round supplies of milk the Continent as a whole has ever had.

Meetings in December

AMERICAN Society of Parasitologists. New Orleans, December 5-8.

Mathematical Association of America. Columbus, Ohio, December 26-31.

THE SUN

Our star is a vast engine for converting matter into radiation. The latter sustains life on earth and also provides some clues for the astronomers

by Armin J. Deutsch

On July 26, 1946, at 11:15 a.m. E.S.T., astronomers saw a hot, scarlet filament lash out across the face of the sun directly over a large, active sunspot. At the moment of its appearance, short-wave radio transmission blacked out over the whole daylit hemisphere of the earth. On one radio frequency, static from the direction of the sun increased to over 10,000 times its normal volume. In the course of the next 10 or 12 minutes the scarlet filament swelled in intensity; for a few seconds it shone 30 times as intensely in its own red light as the brilliant face of the sun. Then, less rapidly than it had appeared, the flare lengthened, spread out and faded. At 12:30 it had twisted over a distance of 350,000 miles; near one edge of the flare a mass of cooler gas covering an area of a billion square miles was seen falling into the sun at a speed of 45 miles a second.

A few hours after the scarlet flare had first erupted, nothing remained to mark its position over the great group of sunspots. But at 1:45 p.m. the next day, sensitive magnetic instruments in observatories all over the earth simultaneously began a sudden, violent trembling. The magnetic field at the surface of the earth jittered for the next 12 hours, then gradually settled down again to its normal untroubled state. The press wireless circuits between New York and the northern capitals of Europe remained useless during most of July 26 and 27. A brilliant aurora illuminated the skies over the eastern seaboard in the early morning hours of the 27th; in Washington colored streamers flickered past the zenith and down into the southern part of the sky.

This phenomenon was not unique. When the face of the sun is well spotted, as it is now during this period of maximum sunspot activity, solar flares are not especially rare. More than 40 were observed at California's Mount Wilson Observatory in 1946, and it is estimated that on the average they occurred as often as one every 50 hours. Most flares, of course, are less intense than the great one of July 26, and many are accompanied by less violent terrestrial effects. Few, if any, are bright enough to show up in an ordinary telescope. Most of them can be seen or photographed only with an instrument that picks out of the sunlight one of the few narrow bands of the electromagnetic spectrum into which the flares concentrate all their energy. The conventional instrument for this purpose is the spectro-

DISK of the sun darkens at the edge, one indication of the rapid thinning of its atmosphere. On the surface is an unusually large group of sunspots.

FLARE on the sun was photographed by light-selective spectrohelioscope. Spectroheliogram is from Michigan's McMath-Hulbert Observatory.

helioscope, which disperses the spectrum of sunlight and passes through a narrow slit just that one particular band of wavelengths which is required to fall on the retina or on the photographic plate. Recently some astronomers have dispensed altogether with the elaborate spectrohelioscope, and have used instead a compact sandwich of thin quartz blocks and slices of Polaroid, which together function as a filter passing a very narrow band of wavelengths.

The Carbon Cycle

The sun, 93 million miles distant from the earth, is some 109 times the diameter of our planet and a third of a million times more massive. Near the center of the sun at a temperature of 20 million degrees Centigrade, a pressure of a billion tons per square inch and a density seven times that of lead—atomic nuclei collide with such violence that one nuclear species may be transformed into another. The most important of these processes builds helium nuclei out of hydrogen. The transformation takes place through a sequence of six nuclear reactions. The sequence begins with a collision between the nucleus of a common carbon atom and a proton, the nucleus of a hydrogen atom. As the result of the impact, the two nuclei unite to form an isotope of nitrogen. But the mass of this new nucleus is slightly less than the sum of the masses of the two colliding particles. The lost mass appears as a burst of radiant energy, in this case a gamma ray.

The newly formed isotope of nitrogen is unstable; within a few minutes of its birth it ejects a positive electron, or positron, and becomes a heavy isotope of carbon. When this collides with another proton, the two nuclei again unite to form an isotope of nitrogen, and the excess mass is again carried off in a gamma ray. Collision with a third proton transforms the nitrogen into oxygen and produces a third gamma ray. But the oxygen is unstable, and it quickly ejects a positron to transform itself back into nitrogen. Encountering a fourth proton, the new nitrogen nucleus splits in two. One fragment is the nucleus of a helium atom; the other is the nucleus of carbon with which the whole sequence of transformations began. The result of the sequence, therefore, is to join four hydrogen nuclei into one helium nucleus, through the catalytic action of carbon. At the end of the cycle, the carbon atom that set it off reappears, ready to catch another proton and start the cycle over again.

In this way, step by step, 564 million tons of the sun's hydrogen are transmuted every second into 560 million tons of helium. Most of the four million tons of mass that melt away every second are con-

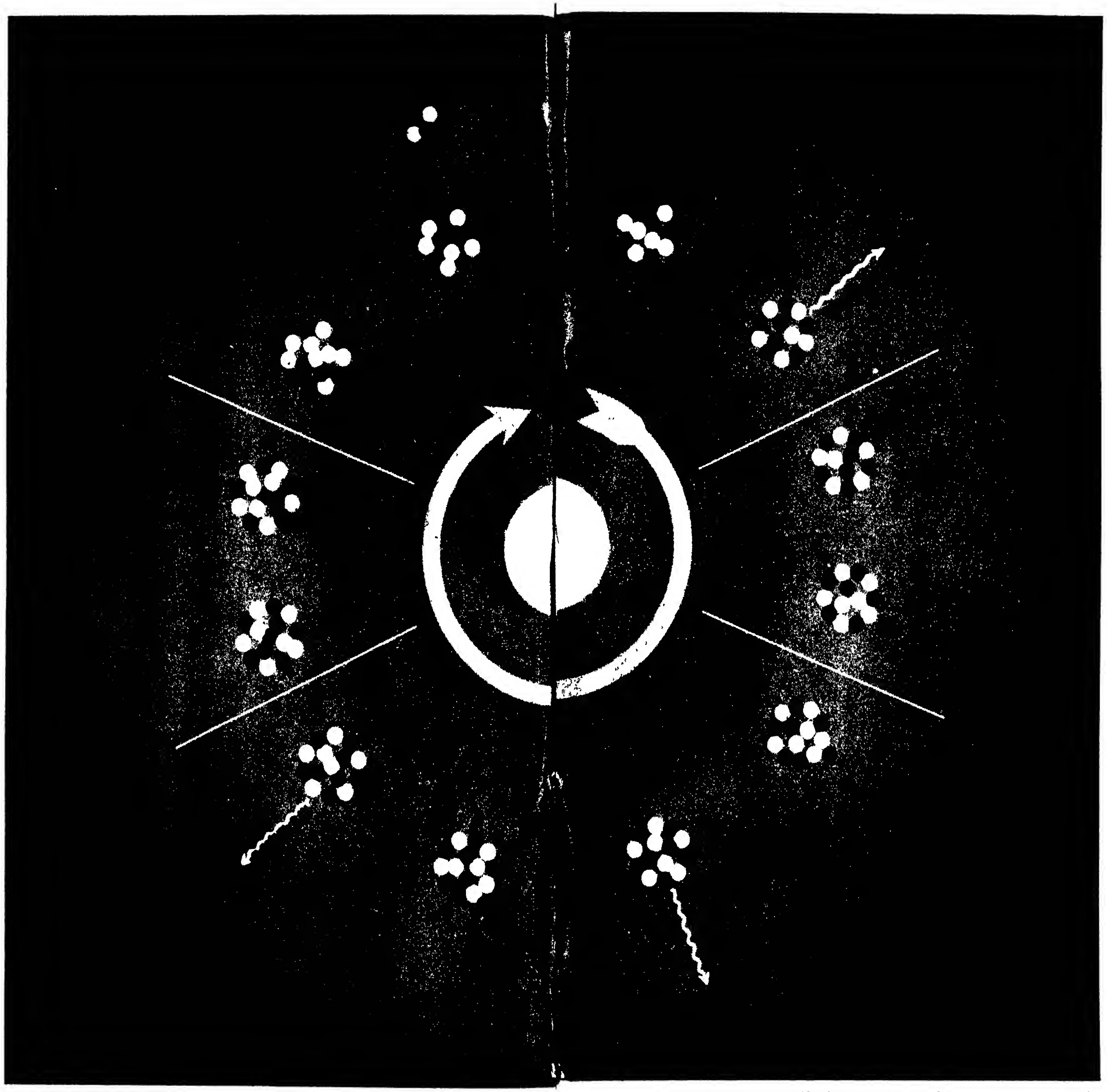
verted into radiant energy, and this flows out from the sun's incandescent surface at the rate of half a million billion billion horsepower. The earth, a small target at its distance from the sun, is struck by less than half a billionth part of the total solar radiation. But that small fraction is enough to hold the temperature of the whole terrestrial surface well above the absolute zero of empty space, to drive the great heat engine that is the atmosphere, to sponsor the complex processes by which plants build living matter from carbon dioxide and water, and, through the plants, to sustain all animal life.

The study of this nearest of all stars has been pursued by astronomers ever since that momentous day in 1610 when Galileo first gazed at its incandescent disk with his new telescope. Galileo actually observed black spots on the sun. At first uncertain whether they were the shadows of bodies lying between the earth and the sun, he soon concluded that they were on the sun itself, and that their motions across the disk from east to west were caused by the rotation of the sun on its axis in a period of nearly a month. Two and a half centuries later, however, Sir John Herschel still could ask, "But what *are* the spots?" The great English astronomer went on to assert that "Many fanciful notions have been broached on this subject, but only one seems to have any degree of physical probability, *viz.*, that they are the dark solid body of the sun itself, laid bare to our view. . . ." Today it is established beyond doubt that the sun has no dark solid body. But astronomers still echo the plaintive query of John Herschel: "What *are* the spots?"

Darkening of the Limb

The spots appear against the background of the bright, white surface of the sun, and this background itself has revealed much to the careful observer. It is not particularly difficult to see, for example, that the disk of the sun is distinctly fainter near the edge than at the center, though the edge itself looks perfectly sharp through the most powerful telescopes. This darkening at the edge, or limb, is even more conspicuous in photographs. It shows up most clearly in blue and violet light, to which the ordinary photographic emulsion is more sensitive than is the eye. Indeed, careful measurements have shown that in the near ultraviolet, the limb of the sun is less than half as bright as the center.

The laws of radiation from hot bodies have enabled us to determine the temperature of the surface of the sun—astronomers call it the photosphere—from its brightness. The temperature is found to be nearly 6,000 degrees above absolute zero (—273 degrees C.). At this temperature all known substances are in a gaseous state. In other words, what seems at first to be the bright, smooth surface of the sun



THE CARBON CYCLE is the chain of nuclear reactions that is the source of the sun's energy. Beginning in the right half of this drawing, the cycle manufactures one helium nucleus, or alpha particle, out of four hydrogen nuclei, with the release of energy. The large circle outside the cycle represents the sphere of the sun. The small circle in the center indicates the relative size of the small zone in the center of the sun where the carbon cycle takes place.

is instead an incandescent atmosphere some 200 miles thick. In the outer regions of this atmospheric shell the solar gases shine only faintly and are almost perfectly transparent; near the bottom of the shell the gases are intensely bright and nearly opaque. The sun's atmosphere, of course, grows less dense and less hot toward the top. Near the base of the photosphere, the temperature is 6,300 degrees absolute; the pressure is about one-fifth that of the earth's atmosphere at sea level, and the density is less than a millionth the sea-level density of air. Two hundred miles above the base of the photosphere, the temperature has fallen 1,400 degrees, the gas pressure and density have decreased 18 times and 12 times, respectively, and the gas has become more than 60 times as transparent.

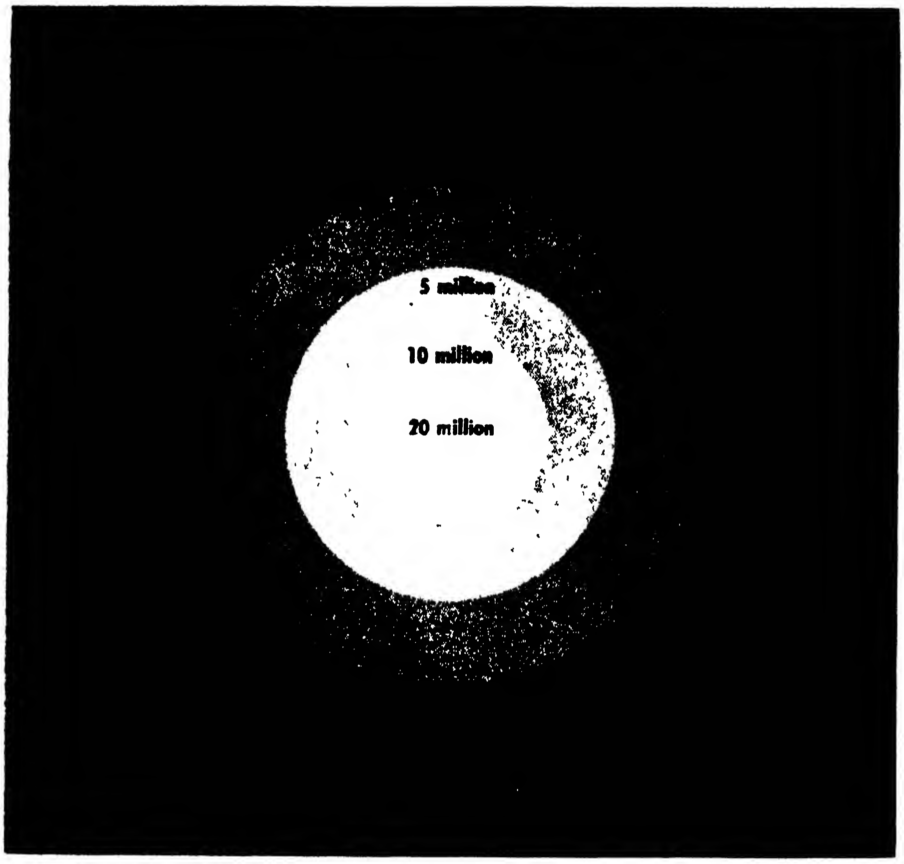
It may seem strange that the bright face of the sun should prove to be nothing more substantial than a mantle of luminous gas which has no sharp boundaries at all. If this picture is the correct one, how are we to account for the razor edge which the disk of the sun shows, even when it is observed through powerful instruments? Why do we not see the atmosphere gradually fade out at the limb of the sun? The reason, of course, is that at a distance of 93 million miles from our telescopes, even an atmosphere over 200 miles thick will look like a sharp edge. at that distance, 200 miles subtends the same angle as a human hair at a distance of 150 feet.

The darkening at the limb of the sun is just a consequence of the fact that we view a semi-transparent atmosphere, not a discrete surface. Near the limb we look obliquely through the sun's atmosphere, and we cannot see as deep into the sun as at the center. The light that reaches us from the center of the disk originates mainly near the bottom of the photosphere, there the temperature is high, and the light we see is correspondingly bright and blue. But the light that comes to us from near the limb starts from near the top of the photosphere; there the temperature is relatively low, and the light is consequently fainter and redder.

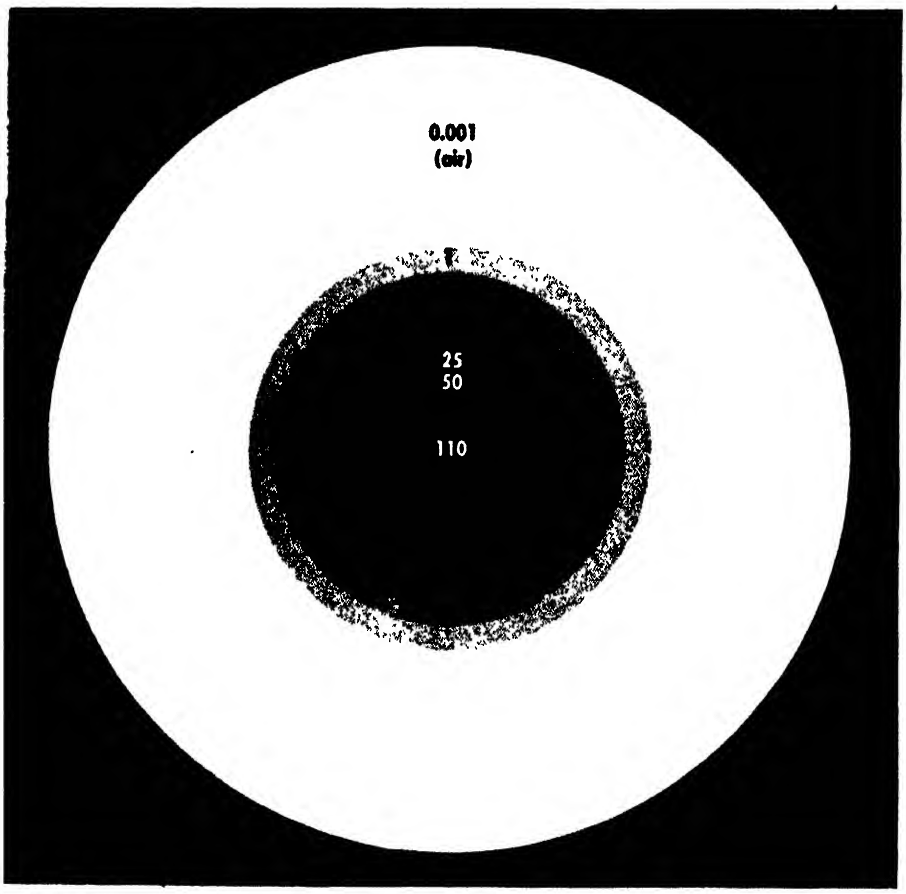
A careful study of the limb-darkening ought, therefore, to convey a great deal of information about the absorbing properties of the photosphere. One of the outstanding puzzles in solar astronomy for many years was the surprising opacity of the tenuous photosphere. There is more gas in the column of air above each square foot of the earth than above each square foot at the base of the photosphere. Yet our atmosphere is almost perfectly transparent, while that of the sun is opaque. The reason for this difference has been ascertained only within the past few years.

The Opaque Photosphere

Consider the behavior of the atoms in the sun's photosphere. Because the temperature is so high, they move about at



TEMPERATURE of the sun is calculated to be 6,000 degrees Centigrade above absolute zero (−273 degrees C.) at the surface and 20 million degrees at the center. Here the sun's intermediate temperatures are also indicated.



DENSITY of matter in the sun's interior is stated in units of the density of water. The density of air is not attained until some distance beneath the photosphere. The density at the center of the sun is 110 times that of water.

great speed. The density is relatively low, so the atoms collide with one another less frequently than do molecules of air on the earth. But when they do meet, the collision is about 20 times as violent, on the average, as that between air molecules. In fact, collisions between atoms in the photosphere, and between light quanta and atoms, often are energetic enough to knock an electron from one of the atoms and to leave the atom as a positive ion. Atoms of the metals are particularly subject to this kind of mutilation, for their electrons are less closely bound than those of most other elements. Consequently, near the base of the photosphere every cubic inch of gas contains in the neighborhood of a million billion unattached electrons that have been knocked out of atoms. The population of these vagrant particles does not increase, because ionized metal atoms snap them up just as fast as others are set free.

Negative Ions

Much more common than the metal atoms, outnumbering them perhaps 8,000 to one, are the atoms of hydrogen. These are the lightest and simplest of all atoms: each is constructed of a massive, positively-charged nucleus and a light, negatively-charged electron. In the hydrogen atom, the electron is very firmly bound to the nucleus, so relatively few hydrogen atoms are ionized. Indeed, a certain small proportion of hydrogen atoms react in a contrary fashion: instead of losing electrons they pick up extra ones from the surrounding crowd. The result is a negative ion of hydrogen—a hydrogen atom with two electrons.

This phenomenon is rare even in the hydrogen-rich photosphere of the sun; it has seldom been detected in terrestrial laboratories, and experiments to determine the properties of negative hydrogen ions have not yet been devised. Nevertheless the modern theory of atomic structure has proved adequate to permit the theoretical description of certain of their properties. The results of these calculations indicate very clearly that such ions are to blame for the opacity of the photosphere.

The reason the negative ions of hydrogen are particularly effective in intercepting the light welling up from the interior of the sun is closely linked to the fact that their extra electrons are easily detached. Ordinary atoms and positively-charged ions usually will let a quantum of infrared or visible light pass. Occasionally they will capture a quantum of ultraviolet light, which is very rich in energy, and the energy will detach an electron from the nucleus. The negative hydrogen ion is less discriminating. Needing only a small amount of energy to free the extra electron, it accomplishes its own demolition by greedily absorbing almost any passing light quantum. It is almost completely in-

different to color: a quantum of weak red light will detach an electron about as well as one of energetic blue light. Thus the negative ions of hydrogen in the photosphere rapidly soak up the light of all colors coming from below. This absorption is what makes the photosphere opaque. Of course, the absorbed light is re-emitted again every time an electron attaches itself to a hydrogen atom to form another negative ion. But the damage is already done; the light from below cannot get through without interference, and so we cannot see through the photosphere.

Although atoms with a normal complement of electrons are less responsive than negative ions of hydrogen to visible light, they are not entirely indifferent to it. Thus a neutral hydrogen atom welcomes the chance to absorb light of a wavelength of 6,563 angstrom units (one angstrom unit = 1/100,000,000 centimeter). A quantum of this particular wavelength contains exactly the amount of energy needed to boost the hydrogen electron from one of its orbits about the nucleus to another. A quantum of slightly redder light will have a longer wavelength and carry only slightly less energy, but the hydrogen atom will invariably let it go by. It is strictly an all-or-nothing proposition: either the hydrogen atom gets just enough energy from the light to push the electron up to another orbit, or else it takes none at all. The hydrogen atom has a neatly systematized collection of orbits for its electron, numbered one, two, three and so on, and it will not tolerate an electron anywhere else. It works very much like a slot machine which will take a nickel or a dime or a quarter but not seventeen cents.

The particular set of wavelengths that a hydrogen atom will condescend to absorb has been determined in the laboratory. The essence of this experiment, without going into its complicated details, is that white light, in which all colors are present, is made to pass through a container filled with atoms of hydrogen. The light that is transmitted by the gas is then spread out into a spectrum, and the colors that have been absorbed by the hydrogen reveal themselves by gaps in the spectrum —dark lines which mark the wavelengths absorbed.

Characteristic Absorption

The whole science of spectroscopy is based upon this fundamental selectivity of light absorption by atoms. Experiments have shown that hydrogen atoms always absorb the same wavelengths, and every other atom likewise has its own pattern. Like the fingerprints of men, the absorption spectra of atoms identify them completely. No iron atom has ever absorbed hydrogen's set of lines, or *vice versa.* It is an essential part of the ironness of iron to absorb only iron lines. Depending upon the temperature of the gas, and upon certain other conditions, some iron lines will be relatively stronger at some times than at others. These effects add complication to the job of the spectroscopist, but they also make it possible for him to discover more about the structure of the atom, and for the astrophysicist to discover more about the structure of the sun.

When the light of the sun is dispersed into a long spectrum, it is found to be deficient in the set of wavelengths that the neutral hydrogen atom absorbs. And of course hydrogen is not the only element that steals the sunlight as it seeps up through the solar atmosphere. Of the 92 chemical elements known to reside in the crust of the earth, some 66 have been found in the atmosphere of the sun by their telltale absorption lines in the solar spectrum. Acting together, these 66 kinds of atoms produce some 25,000 absorption lines which have so far been mapped in the solar spectrum. Some of these lines are broad and almost perfectly black (meaning that almost all of the light at these wavelengths has been absorbed), others are narrow and pass most of the light within them. The strength, or total blackness, of any absorption line—a line produced by iron, say—obviously depends on the abundance of that element in the solar atmosphere. Thus a quantitative analysis of the solar atmosphere is possible.

It turns out that the strength of an absorption line depends on many other things besides the abundance of atoms—the temperature of the source, the number of free electrons in the vicinity, the electronic structure of the atoms concerned. All these factors, and several others too, must be taken into account before the chemical composition of the atmosphere is finally obtained. The problem is by no means completely solved today, but the indications are strong that most of the elements occur in the solar atmosphere in very nearly the same relative abundance as in the crust of the earth. The outstanding exceptions are hydrogen and helium, which are enormously more common on the sun than on the earth, presumably because our planet does not have sufficient gravitational attraction to have held these light gases. The fact that there are 26 natural elements whose absorption lines have not yet been found in the solar spectrum is not surprising, for most of them are so rare on the earth that we do not expect to be able to detect them in the sun.

In addition to the absorption lines of most of the chemical elements, the spectrum of the sun exhibits some of the intricate absorption patterns that are characteristic of molecules. A recent count of these so-called absorption bands indicates that at least 18 different two-atom molecules can be identified in the sun. But molecules do not fare well in the rough-and-tumble of the solar atmosphere. Collisions with atoms and with light quanta are too frequent and too violent, with the result that after a chance encounter of two atoms with a chemical affinity, the resulting molecular union is always broken within a split second. There is virtually no chance for a diatomic molecule to survive long enough to meet and pick up a third atom, and even among the simple diatomic molecules, only the hardiest survive long enough to be able to make a showing. The ubiquitous hydrogen atoms manage to work themselves into most of the chemical compounds that are found. Among the commonest are the combinations formed by hydrogen with nitrogen, carbon and silicon. A few oxides, and probably two fluorides, also occur.

All these molecules, and the much more abundant atoms too, are the obstructionists of the solar atmosphere. Even if a quantum of light runs the gamut of negative ions of hydrogen in the 200-mile-thick photosphere, it is unlikely to escape the sun if its wavelength coincides with the wavelength of one of the thousands of absorption lines in the solar spectrum. If its wavelength happens to be one of those that can be absorbed by a hydrogen atom, for example, the quantum has practically no chance of escaping, for it is almost certain to collide with a hydrogen atom in the rarefied layers above the top of the photosphere. These uppermost reaches, though transparent to light of most wavelengths, are still opaque in the wavelengths that hydrogen can absorb. Light of these colors has a fair chance to escape the sun only if it is produced high above the top of the photosphere, where few hydrogen atoms stand in its way.

Monochromatic Photographs

Because of this fact, the isolation of the small amount of light that comes to us from the center of one of the strong, dark absorption lines enables us to take a photograph of the topmost levels of the solar atmosphere. Similarly, isolation of the light slightly off the center of the line, but still within the range of wavelengths absorbed by hydrogen, permits a photograph to be taken of a level intermediate between the photosphere and the top of the extremely diffuse gas above it. The sun has many faces; by a judicious selection of the color of light we admit to our camera, we can photograph them one by one.

Monochromatic photographs of this kind reveal a vast and turbulent atmosphere extending more than 5,000 miles above the top of the photosphere. In the lower levels of this surprising solar envelope, which is known as the chromosphere, the temperature and density of the gas fall off with increasing height at about the same rate as in the lower, opaque levels—a rate which keeps the gas pressure just balanced against the solar gravity. But after the density has fallen several hundredfold, the gas quite abruptly stops thinning out at the expected rate, and the temperature actually seems to start going up again. In this part of the sun, the atoms are so

sparsely strewn that the "temperature" we measure depends on the method we use to measure it. The relative strength of the various lines of hydrogen correspond to a temperature of 10,000 degrees absolute, but the shapes of the lines indicate that the atoms are moving at speeds corresponding to a temperature twice that high, and the very slow thinning out of the hydrogen atoms at great heights seems to indicate a temperature near 30,000 degrees.

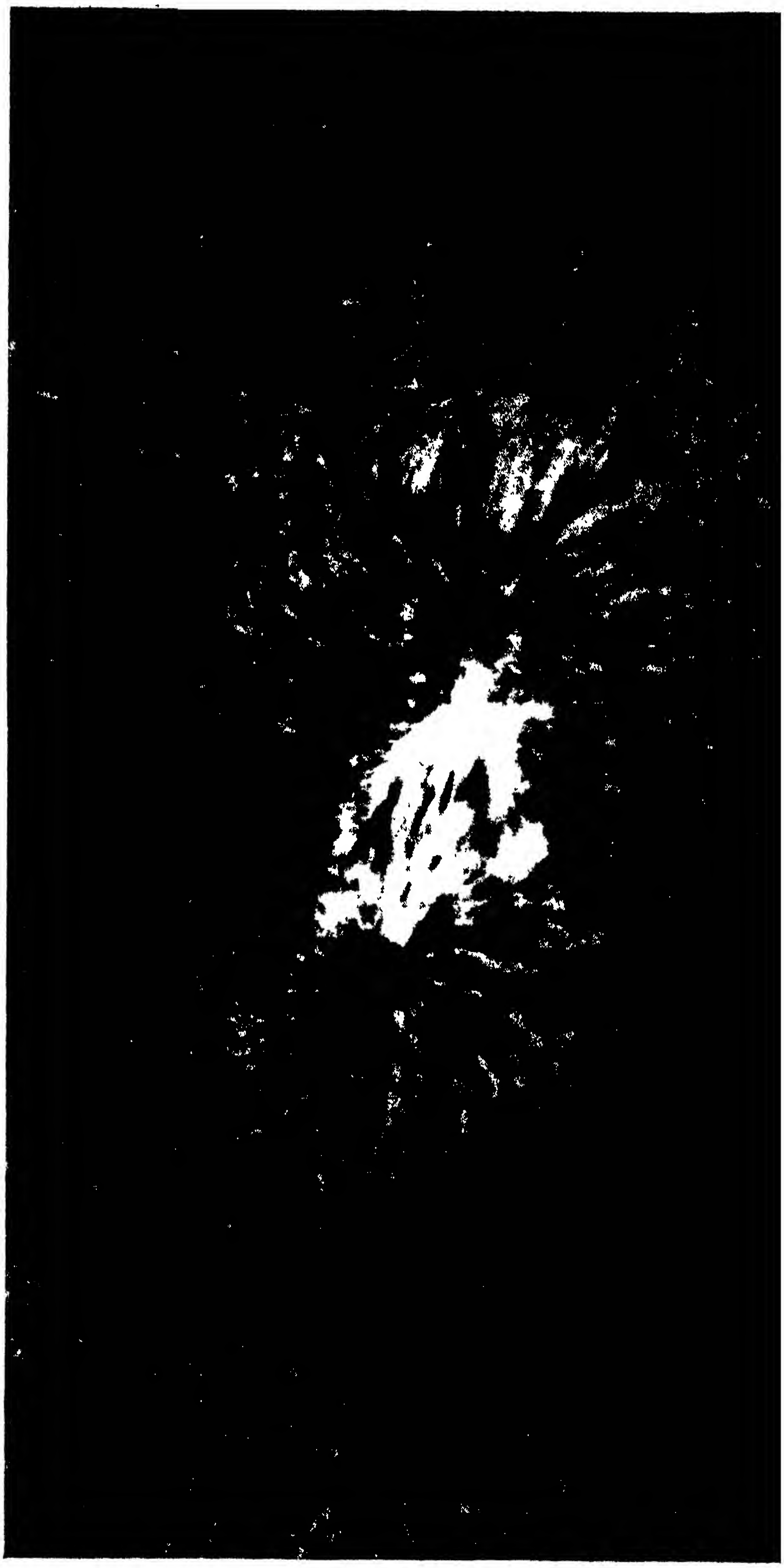
The appearance of the chromosphere at any time depends on the wavelength of the light in which we view it. Photographed in one of the colors strongly absorbed by ionized calcium, the face of the sun looks curiously like the peel of an orange. Against the irregular, mottled background, there frequently appear a few long, thin, dark filaments. These irregular black scars appear also on photographs exposed in the light of one of the hydrogen lines, but the rest of the detail in the hydrogen photographs is more irregular than in calcium light. The true nature of the dark filaments becomes apparent when the rotation of the sun carries one of them to the limb. Projected then against the black sky, instead of against the glowing chromosphere, the filaments are seen to be great flamelike protuberances from the chromosphere. Called prominences, these irregular objects commonly extend 30,000 miles above the chromosphere itself, and many are several times that high.

The Prominences

Prominences are apt to appear in any solar latitude. They assume a variety of forms, but usually they are curtain-shaped, their thickness being small compared with their length and height. An average prominence will have a length of 125,000 miles and a thickness of only 6,000 miles.

The mass of an average prominence is probably about the same as the mass of the water in Lake Michigan. In some prominences, the gases do not appear to be in rapid motion; for days at a time the great heap of gas may maintain unchanged its general shape and its position on the sun. Other prominences exhibit intricate patterns of motion, best studied by motion pictures. Knots of gas are commonly observed to describe gracefully curved trajectories down towards the chromosphere, and speeds of the order of tens of thousands of miles per hour are the rule. But the motions are by no means always in the same direction. In one and the same prominence, some gas can be seen ascending while other gas is descending, and frequently knots of matter will

SUNSPOT appears as a great vortex in the photosphere. Although the temperature of the spot is some 5,000 degrees, it appears dark because it is cooler than the surrounding area.



SPECTROHELIOGRAM of a sunspot shows whorls of gas resembling the lines of force in iron filings that are sprinkled on paper above the poles of a magnet. This spectroheliogram was made by one wavelength emitted by hydrogen. It shows disturbances in the chromosphere, the layer above the photosphere. In this case the disturbances are huge clouds of hot hydrogen.

CHANGES IN SUNSPOT form are shown by a series of spectroheliograms made as the sun turns. This spectroheliogram, like the one that appears on the previous page, is produced by one spectral line of hydrogen. Pat-

drift along nearly parallel with the top of the chromosphere, meeting and passing other condensations moving in the opposite direction.

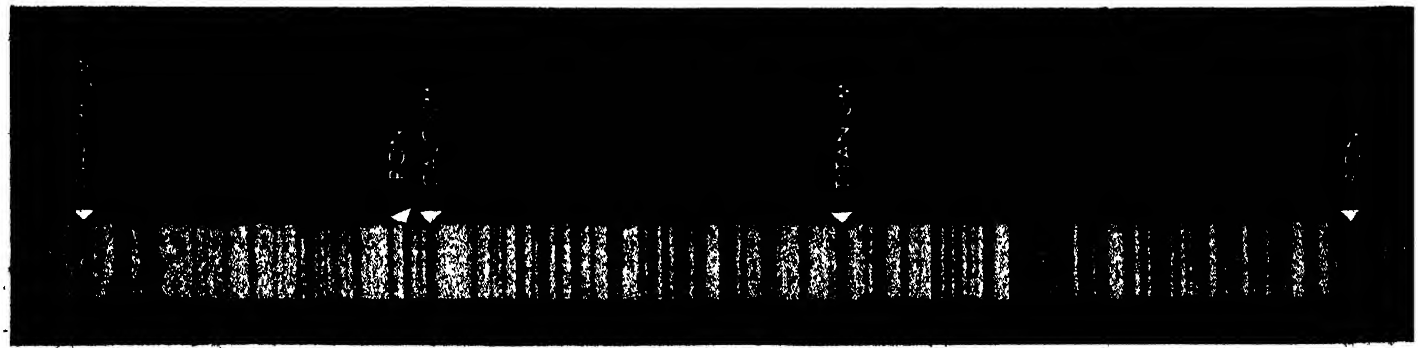
The forces acting on prominence material, like the forces which levitate the whole distended chromosphere, are not yet understood. Whatever the nature of these forces, they sometimes produce the most puzzling and awesome phenomena. Tornadolike prominences occasionally whirl straight up to 100,000 miles above the chromosphere. Narrow tongues of gas shoot out of the region above a sunspot at speeds of 100 miles a second. After reaching out to a height of perhaps 100,000 miles, the gas will as suddenly appear to be retracted, sliding back into the sun without any apparent loss of matter. Occasionally a prominence is literally blown off the sun. A prominence which has quietly arched across 250,000 miles of the chromosphere for days on end will suddenly explode, and the gas will be impelled outwards at speeds of hundreds of miles a second.

Before the invention of the spectrohelioscope, the prominences and the chromosphere could be observed only when the sun was totally eclipsed. With the brilliant photosphere hidden behind the dark disk of the moon, the red ring of the chromosphere and the flamelike protuberances are often visible even to the unaided eye. A still more extensive envelope around the sun also becomes apparent during a total eclipse. Called the corona, this vast pearly halo reaches out into space as much as a million miles in some directions. Although it gives half as much light as the full moon, the corona for many years defied all efforts to see or photograph it outside of total eclipse. Unlike the prominences, the corona does not concentrate most of its light in a few isolated colors; it shines in all colors, and these are mixed in nearly the same proportions as in light from the photosphere. Except during eclipse, minute imperfections in the telescope lens, or even microscopic dust particles in the air itself, scatter enough photospheric light into the million-times fainter coronal image to drown it out completely.

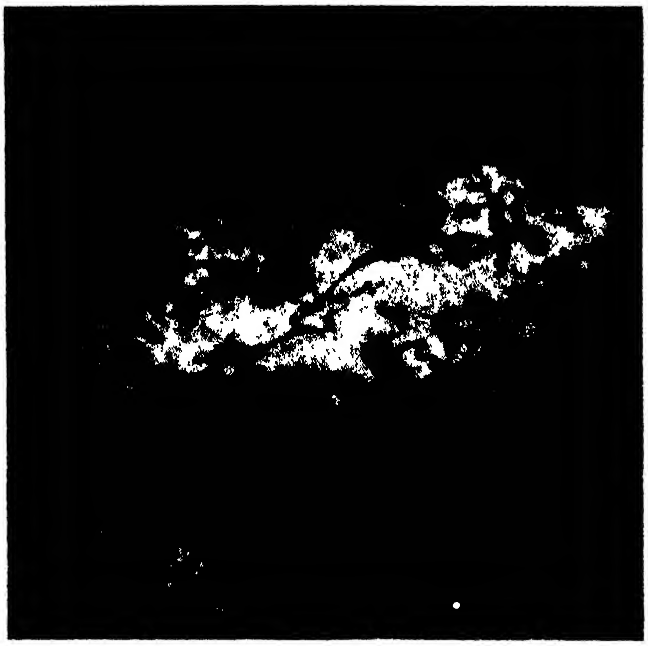
The problem of observing the corona was first solved in 1930 by Bernard Lyot, a young French astronomer. He devised a special kind of telescope using a simple lens of superb optical quality, and fitted it with light traps to deflect out of the image all the photospheric light. He transported the whole instrument to the top of the 9,400-foot Pic du Midi, in the Pyrenees, where the air is unusually pure and serene. On his first attempt, Lyot succeeded where so many before him had failed; he could detect the corona outside of eclipse. Following Lyot, several other coronagraphs have been erected at high elevations in Europe. The only one in the Western Hemisphere, operated jointly by Harvard College Observatory and the University of Colorado, is at a site in the Colorado Rockies 11,500 feet above sea level.

The Corona's Color

The color of the coronal light, and its state of polarization, both suggest that it consists mainly of photospheric light, reflected to the earth by an extremely diffuse cloud of electrons around the sun. But the light that reaches us from within 100,000 miles of the photosphere does not show



SPECTRUM OF THE SUN shows an intricate series of dark lines indicating the characteristic wavelengths absorbed by the atoms of various elements in the solar atmosphere. The elements, and one compound, that ac-



terns in the gas again indicate a magnetic field about the spots. When sunspots are paired, the magnetic field of one usually has a polarity opposite that of the other. These photographs are from Mount Wilson Observatory.

any of the absorption lines that we expect to find in reflected sunlight. Their absence can be accounted for only by supposing that the reflecting electrons are moving in all directions with speeds averaging some 2,000 miles a second! Speeds as great as this imply a temperature of over 500,000 degrees absolute. Can the corona really be as hot as that?

Evidence that it can and must be is provided by the excessive brightness of certain colors in the coronal spectrum. The spectrum shows a line at 5,303 angstroms, for example, which is not a dark absorption line but a bright line representing an excess of light. Elsewhere in the spectrum appear about 25 other so-called emission lines. Unlike the spectral lines that appear in the light from other parts of the sun, these emission lines in the spectrum of the corona have never been duplicated in any terrestrial laboratory. Nor are they likely to be duplicated in the foreseeable future, for they are the so-called forbidden lines—colors which an atom is extremely reluctant to radiate and will not radiate at all unless left undisturbed by collisions for seconds or minutes at a time.

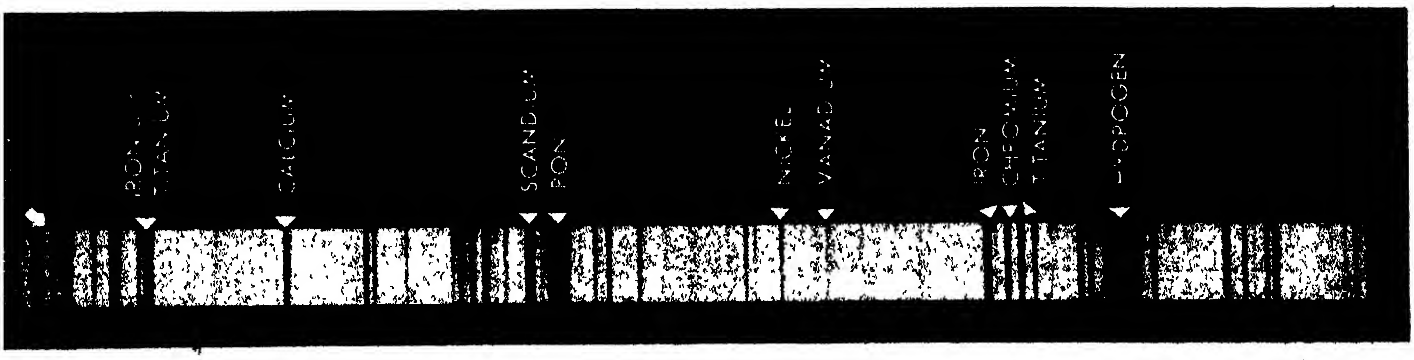
The emission line at 5,303 angstroms, which usually is the brightest one of all, is known to be produced only by iron atoms. But ordinary, electrically neutral iron atoms cannot do the job; it takes an iron atom that has been stripped of 13 of its 26 planetary electrons to radiate light of this wavelength. Other coronal emission lines come from iron atoms which have lost anywhere from 9 to 14 electrons. Atoms of nickel stripped of about half of their normal retinue of 28 planetary electrons also appear in the corona. Still other contributors to the coronal spectrum are highly ionized atoms of calcium and argon.

Now it requires a fairly energetic collision to jolt even one electron off an iron atom, and a much harder collision to remove a second electron once the first is gone. But to remove 13 electrons! This can happen only under conditions of extremely violent impacts, either with other atoms or with very energetic light quanta, and impacts of such violence occur only at temperatures of 500,000 degrees or higher.

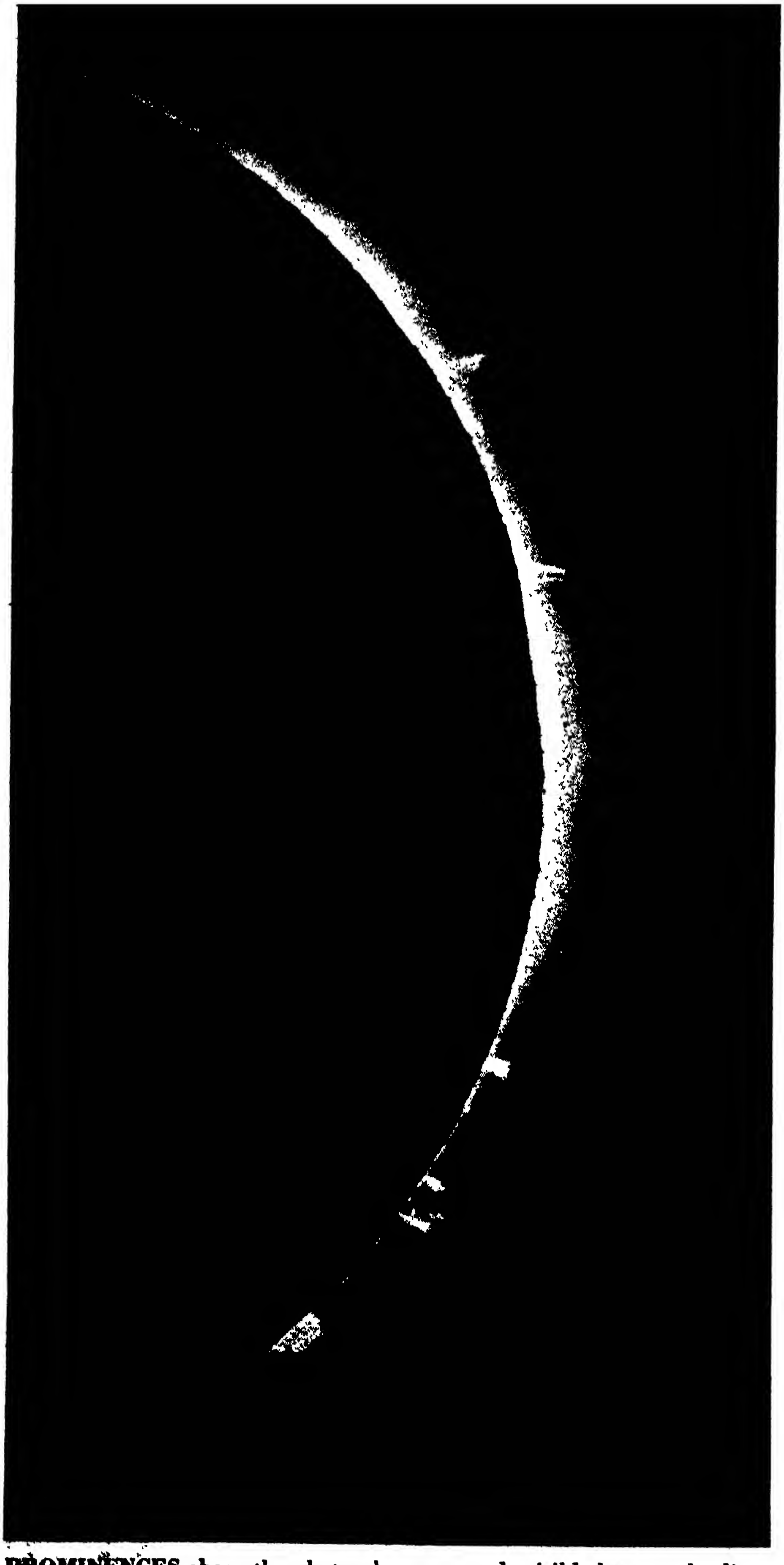
The cause of this remarkably high temperature of the corona is unknown. Some have suggested that it may indicate the ejection of relatively small quantities of gas from the extremely hot interior of the sun through unrecognized "cracks" in the photosphere. Or it may mean that powerful ultraviolet light escapes from the sun through small, undiscovered "pores" in the photosphere. Others have considered the possibility that the overheated atoms of the corona are fission fragments, the end products of nuclear reactions similar to those in an atomic bomb.

Sunspots

Under spectroscopic analysis, what seemed to be the "surface" of the sun has been shown to be a relatively thin layer of opaque gas, buried at the base of an ordinarily invisible envelope that extends, with ever greater tenuity, to a height of hundreds of thousands of miles. A sunspot on the photosphere is only one aspect of a disturbance which extends thousands of miles up through the chromosphere, and frequently tens of thousands of miles higher into the corona. And the spots themselves are only one manifestation of a re-



count for some of the lines are indicated above the spectrum. This strip is only a small part of the entire visible spectrum of the sun. On this scale the full length of the solar spectrum would extend more than 35 feet.



PROMINENCES above the photosphere are made visible by a total eclipse of the sun. Also visible is the luminous ring of the chromosphere. Some prominences hurtle through the solar atmosphere at speeds of hundreds of miles a second; others may remain as almost stationary heaps of gas for days.

current phenomenon which profoundly affects all the parts of the sun accessible to observation.

Stated concisely, the facts about the sunspots are these. In size, they range from specks less than 500 miles in diameter, barely resolvable through a telescope, to great, naked-eye objects more than 50,000 miles across. They look dark because they are 1,000 or 1,500 degrees cooler than the surrounding photospheric gases. They have a tendency to form in pairs, one lying nearly due east of the other; occasionally they form a complex group of many spots which blackens an area of several billion square miles. Small spots ordinarily endure for only a few days; large spot groups may persist for two or three months or even longer.

Chromospheric Clouds

The chromosphere above a sunspot usually exhibits clouds of ionized calcium and hydrogen which are hotter than the surrounding gas. These high, hot clouds commonly form before the spot itself can be seen on the photosphere, and they usually last longer than the spot. If exposed to the light of hydrogen a photograph of the chromosphere above a spot often shows a pronounced vortical pattern suggesting a great whirlpool, but the motions of the chromospheric gas are usually not rapid. In hydrogen light the chromospheric pattern around a pair of spots often closely resembles the lines of force around the poles of a horseshoe magnet as delineated by iron filings scattered on a card held above the poles.

Many absorption lines in the spectrum of a sunspot are found to be polarized and split into several components, an effect which is produced whenever absorbing atoms are subject to a strong magnetic field. By measuring the magnitude of the splitting and the direction of the polarization, it has been possible to find the strength and direction of the magnetic fields in the spots. The direction of the magnetic field near the center of the spot is generally straight up or straight down; its strength is sometimes as great as 4,000 gauss, or 8,000 times the maximum strength of the magnetic field at the surface of the earth.

Sunspots never occur within 45 degrees of either pole of the sun. Their numbers fluctuate with a period that averages 11.3 years, but the interval from one date of maximum spottedness to the next may be several years greater or smaller than this. At sunspot minimum, the few spots which appear are small ones far from the solar equator. As the number of spots gradually increases, the spots themselves grow larger and appear in lower solar latitudes. At sunspot maximum, most of the spots appear at latitudes 10 degrees north and south of the solar equator. Then as the spottedness decreases again, the spots approach nearer the equator; at minimum,

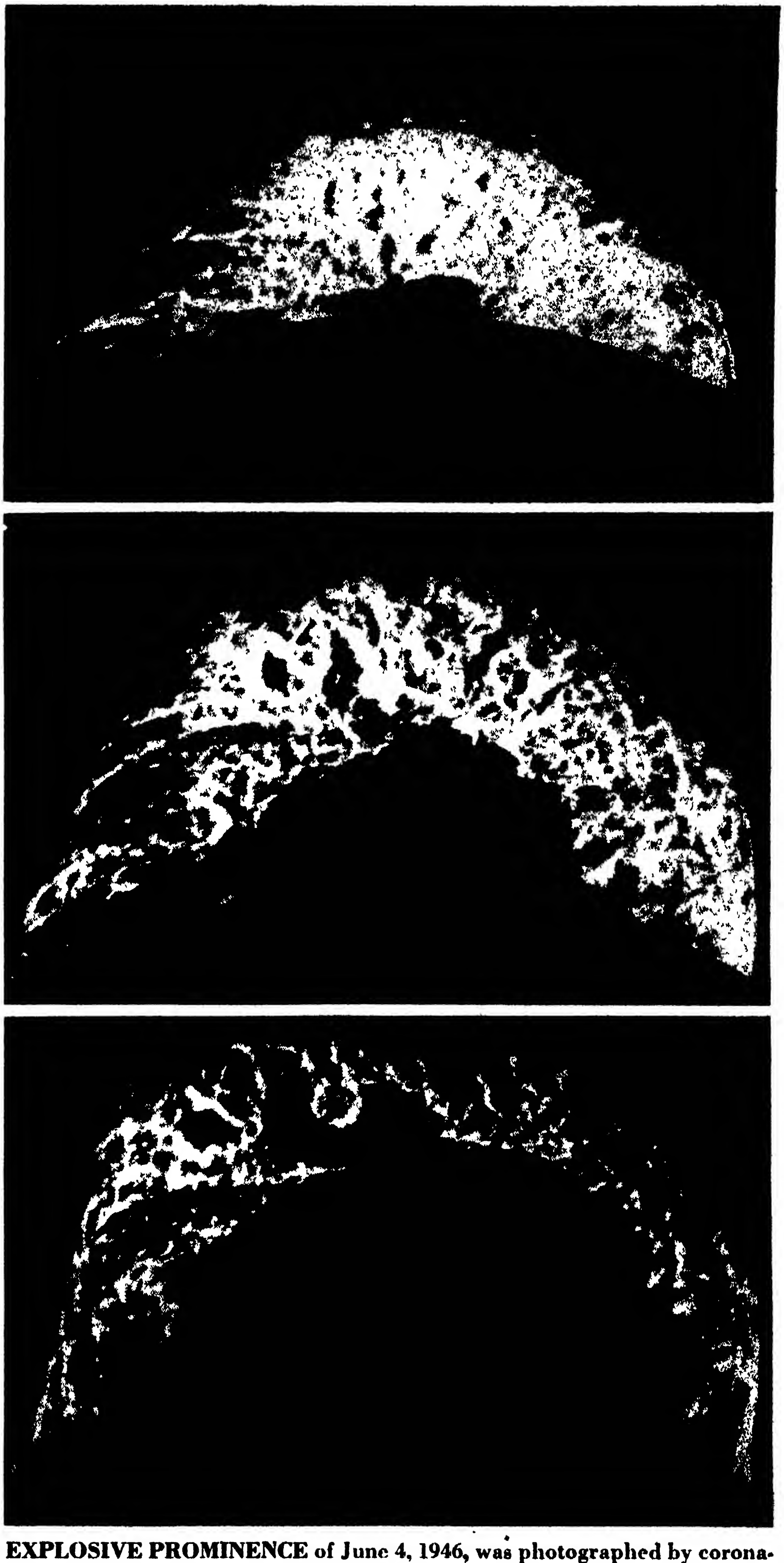
the last small spots of the old cycle lie very near the equator, while the first small spots of the new cycle begin to break out again in high solar latitudes. Throughout any one cycle, almost all pairs of spots in the northern hemisphere have their magnetic polarities paired as to direction; for example, in most northern hemisphere pairs, the easternmost spot will have north magnetic polarity; the westernmost, south. The arrangement of polarities will be just the opposite in southern hemisphere spot pairs. But in pairs of the next following spot cycle, the law of magnetic polarities will be reversed in both hemispheres.

When the solar rotation carries a sunspot to the limb, prominence activity can commonly be seen above the spot. Frequently material seems to "condense" out of the corona, where it is invisible in hydrogen light, and to descend into the spot in the form of brightening streamers.

Above other spots, clouds of rapidly changing form and structure appear. Often the cloud is fed by streamers curving in from the invisible corona and depleted by other curved streamers converging to a center of attraction in or near the spot. On occasion, the mysterious center of attraction appears to become too strong: great pieces of the high cloud may be torn off and drawn downward, and sometimes the whole prominence will suddenly rise several thousand miles upwards, then turn and plunge down into the center of attraction. Above groups of spots, archlike prominences will occasionally connect spots separated by some 25,000 miles, the gas usually ascending along one side of the arch and descending along the other. Solar flares, like the great eruption of July, 1946, generally occur over or near spots, and therefore are much more frequent near spot maximum. They may be related to certain kinds of unusually bright prominences, but they seem to occur at somewhat lower levels than the prominences. The prominences themselves are often not associated with spots or with any other detectable photospheric markings, but their numbers and distribution over the chromosphere change conspicuously with the sunspot cycle. Other characteristics of the chromosphere also vary with the number of spots.

Coronal Changes

Even the vast corona changes its shape and structure with the same rhythm. At sunspot maximum, the outline of the corona is nearly circular. In the inner corona, within 100,000 miles of the photosphere, however, archlike structures appear; the light from these frequently shows unusually bright emission lines. No motion has been detected in such coronal features, but within them there are often prominences and, below them, sunspots. At sunspot minimum, the corona changes its over-all shape, expanding near the solar equator and contracting near the



EXPLOSIVE PROMINENCE of June 4, 1946, was photographed by coronagraph at Climax, Colo. The time elapsed between the photograph at the top and the one at the bottom is 48 minutes. The sun's disk, artificially blacked out by the coronagraph, is arc that appears at the botton of each picture.

poles. A number of short, curved rays appear—reminiscent, again, of magnetic lines of force.

The resemblance is probably more than a coincidence. In 1913 the distinguished American astronomer George Ellery Hale first studied the polarization of the absorption lines in the spectrum of undisturbed regions of the solar disk. He concluded that the sun has a general magnetic field similar to that of the earth, but about a hundred times stronger. Like the much weaker magnetic field of the earth, the field of the sun has an unknown origin. Recently the suggestion has been made that a magnetic field is a fundamental attribute of every large, rotating body, and a simple formula has been discovered which seems to relate the magnetic fields of the earth, the sun and a star to the amount of their respective spins. But the full truth about the magnetic fields of astronomical bodies is not likely to be known in the near future.

Solar Magnetic Effects

There can be no doubt that the magnetic field of the earth is subtly linked to the sun itself. At any point on the earth, small changes in both the strength and the direction of the magnetic force occur almost continuously, but they tend to be much greater at sunspot maximum than at minimum. Isolated magnetic disturbances of moderate intensity show a strong tendency to recur at intervals of 27 days, which is just the apparent rotation period of the spot zones on the sun. Great magnetic storms such as the one of July, 1946, most often occur when a large, active sunspot is near the center of the solar disk. Sunspots covering a total area of more than three and a half billion square miles were photographed near the center of the disk on January 24, 1926; on January 18, 1938; on February 5, 1946; and on July 27, 1946. Within four days of each of these dates, great magnetic storms were observed on the earth.

But the connection between sunspots and magnetic storms is not as simple and direct as these observations might lead one to suppose. As a matter of fact, on three other occasions when sunspots as large as those just mentioned appeared, there were only small magnetic storms, and the biggest sunspot ever recorded—one of over six billion square miles in April, 1947—produced no magnetic storm at all. Moreover, magnetic storms sometimes occur when no spots, or only a few small ones, can be seen on the sun. Further, there seems to be no very close correlation between the times when the seven giant spots that did cause storms were nearest the center of the disk—"pointed" most directly toward the earth—and the times when the storms began. In one case, the magnetic storm began more than four days before the corresponding spot reached the center line of the disk: in another case, the storm was delayed until four days after the spot had crossed the center line.

Perhaps great magnetic storms are produced on the earth only when one or more brilliant flares occur in the chromosphere. Such flares were observed in each of the four largest spots that have caused great magnetic storms, and in none of the four other spots of comparable size that produced only small storms or none at all. Moreover, each of the four flares was followed by a magnetic storm very nearly one day after the flare was observed.

Since magnetism and electricity are closely related, we are naturally led to suspect that electrified particles are somehow ejected from the region of a sunspot during a flare, and that their impact against the earth one day later is responsible for the magnetic storms. To complete the 93 million-mile trip to the earth in one day, these particles must travel with an average speed of about 1,000 miles a second. The bright aurora that so frequently accompanies a magnetic storm is good evidence that the air at heights of 50 to 100 miles is indeed bombarded by energetic particles expelled from the sun.

But the earth need not wait a full day before it feels the effects of one of these furious eruptions on the sun. We have already seen that short-wave radio transmission blacks out at the moment the flare is observed. This implies that something is able to keep pace with the light from the flare as it races across the 93 million miles from sun to earth in just over eight minutes. That "something" can only be some other kind of light, for nothing else can move so fast. A sudden fierce blast of ultraviolet light upon the upper air would, indeed, put a temporary stop to short-wave radio propagation. Radio waves, it is well known, do not travel directly from a transmitter to a distant receiver; they strike the electrified layers of the upper atmosphere (the ionosphere), are reflected back to the earth and in this way are enabled to travel around the earth's curvature. When a shower of powerful ultraviolet radiation strikes the upper air, however, so many molecules are ionized that this region of the atmosphere becomes a great electrical blotter, soaking up and absorbing the radio waves from below instead of reflecting them back to earth.

Absorbed Ultraviolet

So efficiently does the air above us absorb these energetic ultraviolet rays from the sun that virtually none reaches the ground. This shielding action of the atmosphere is probably beneficent to the health of men, but it prevents astronomers from observing directly just those parts of the sunlight that have the greatest effect upon the atmosphere. Judging from the electrical condition of the upper air, and from the spectrum of the sky at twilight, there is good reason to believe that the sun usually radiates far more ultraviolet light than can come from the photosphere, with its relatively low temperature of about 6,000 degrees. These suspicions about the ultraviolet part of the solar spectrum may soon be verified by photographs taken from V-2 rockets at altitudes of 100 miles or so above sea level.

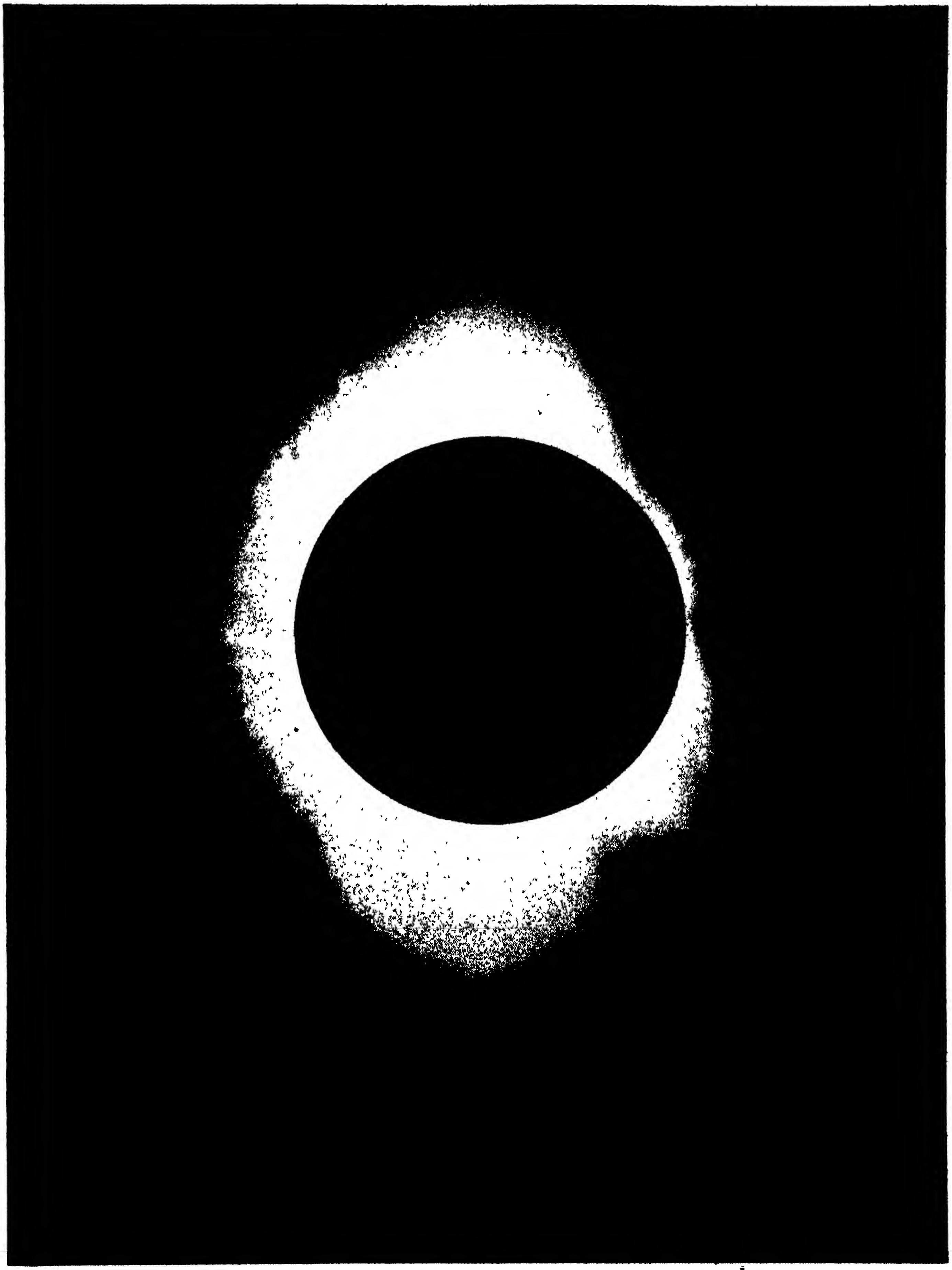
Solar Radio Waves

Not only does the sun govern the propagation of radio waves generated on the earth; it also broadcasts its own radio waves to the earth! This fact becomes a little less startling when we recall that radio and light are both electromagnetic waves. The essential difference between them is just one of wavelength; even a very short radio wave is some 10 million times longer than a wave of visible light. Exploration of the radio spectrum of the sun has begun only within the past few years, but already some surprising results have been achieved. Thus, while the sun seems to radiate on some wavelengths at just the rate to be expected from a photospheric temperature of nearly 6,000 degrees, on other wavelengths it transmits at a power much too high for this temperature. At least some of the excess transmission often comes from the regions around large, active sunspots. In the 5-meter band, for example, radio energy sometimes pours out of a sunspot as though the temperature at the "transmitter" were over a billion degrees!

Perhaps we shall not be able to understand all this tremendous activity throughout the observable parts of the sun until we can give the answer to Herschel's question: "But what *are* the spots?" Today we can give only an incomplete answer. Some astronomers liken the spots to cyclones in the terrestrial atmosphere, and the flares to tornadoes. There is a general tendency to associate the intense magnetic fields of the spots with vortical motion. Since the gas is highly ionized, rotational motion may produce strong electric currents, and these, in turn, may be responsible for the magnetic fields. Recently it has been suggested that flares are comparable to electric discharges: that the changes in the magnetic field of a spot induce currents of electrons in the chromosphere.

There can be little doubt that much of this intense, semi-periodic activity in and above the photosphere is caused by some deep-seated disturbance within the hidden bulk of the sun. For a full understanding of what we see on the sun, we shall probably have to gain a fuller knowledge of what we cannot see—the intensely hot interior, where the atomic fires burn. The task will not be easy. The face of the sun is not without expression, but it tells us precious little of what is in its heart.

Armin J. Deutsch is instructor of astronomy at Harvard University.



SOLAR CORONA, like the prominences on page 36, is made visible when the moon passes in front of the sun. The fine rays in the corona may be effect of the sun's magnetic field. The shape of the corona varies with the 11.3-year cycle of sunspot activity. The principal astrophysical interest of the corona is that it appears to be much hotter than the surface of the sun. This photograph was made by Lick Observatory during an eclipse in 1932.

EROSION BY RAINDROP

The impact of an individual drop on the soil does surprising damage. Multiplied by the billions, it is one of the major problems of soil conservation

by W. D. Ellison

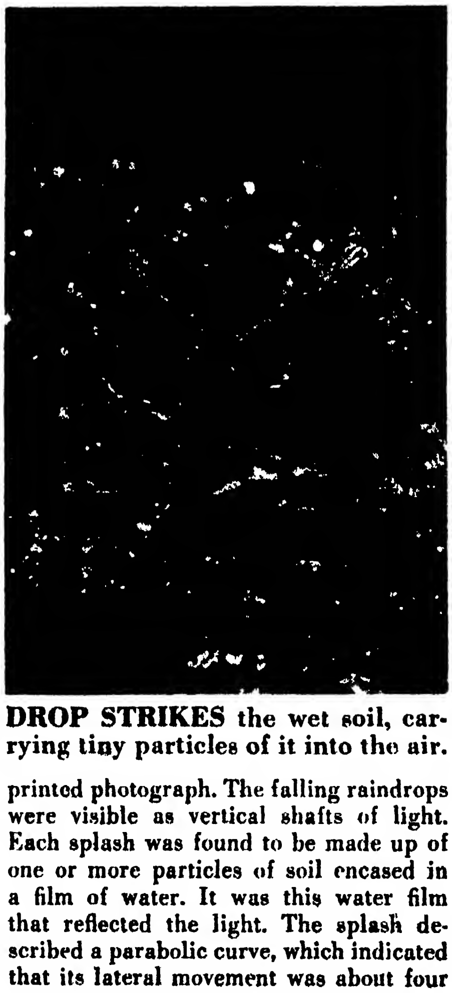
MOST of us have observed the small but violent phenomenon of raindrops splashing on a pavement. On a dark, rainy night, in the beam of a car's headlights the splashes rise like miniature sparkling fountains. On bare earth we see no splashes, yet obviously raindrops must shatter and rebound there too; the difference is that the small splashes, charged with soil particles, are muddy, and more intensive lighting is needed to make them visible.

The displacement of soil by the splash of raindrops is of course a form of erosion, but there has seemed little reason to take it seriously, and until recently no one did. It is not until one makes experimental tests and finds that the impact of raindrops in a violent storm may blast more than 100 tons of soil per acre into the air, and then examines closely what becomes of the blasted soil, that raindrop erosion begins to look like something more than a trifling affair.

The old saying that what you don't know can't hurt you does not apply to splash erosion. We have not known much about this process, but we are learning that it has been hurting us a great deal. Water erosion has generally been thought of solely as the washing of soil by flowing water. We know now that on some soils and terrain, wash-off losses actually account for less than 10 per cent of the erosional damage from a heavy rain; the other 90-odd per cent of loss is attributable primarily to raindrop splashes.

It was while examining an eroded area in my garden that I first noticed the effect of raindrops. I discovered many tiny columns of soil, each capped by a fragment of rock. Each of the odd-shaped columns or pedestals conformed in cross section to the shape of the stone cap protecting it. It was evident that the cap-rock had protected the soil beneath it from raindrops, while the soil around the rock had been splashed away and transported downhill. This theory was consistent with a previous observation: that erosional damage to a field was usually in direct proportion to the intensity of the noise made by raindrops striking on the roof.

The first step in testing the splash theory was to determine whether raindrop splashes could carry significant amounts of soil. I held a small card about an inch from the ground while rain was falling. This soon became spattered with mud. Then I exposed pans of soil with metal disks on top. More than one inch of soil was splashed out during 75 minutes of heavy rainfall, and a soil pedestal was formed under each disk. The next step was to make these splashes visible so they could be photographed. This was accomplished with mirrors which directed light beams across the soil's surface. With a camera time-setting of 1/25 second, trajectories of the flying splashes were made to appear as short arcs of light in the printed photograph. The falling raindrops were visible as vertical shafts of light. Each splash was found to be made up of one or more particles of soil encased in a film of water. It was this water film that reflected the light. The splash described a parabolic curve, which indicated that its lateral movement was about four times its height of rise. Only a few stray splashes rise more than two feet; it appears that some 90 per cent of them may be found within one foot of the surface.



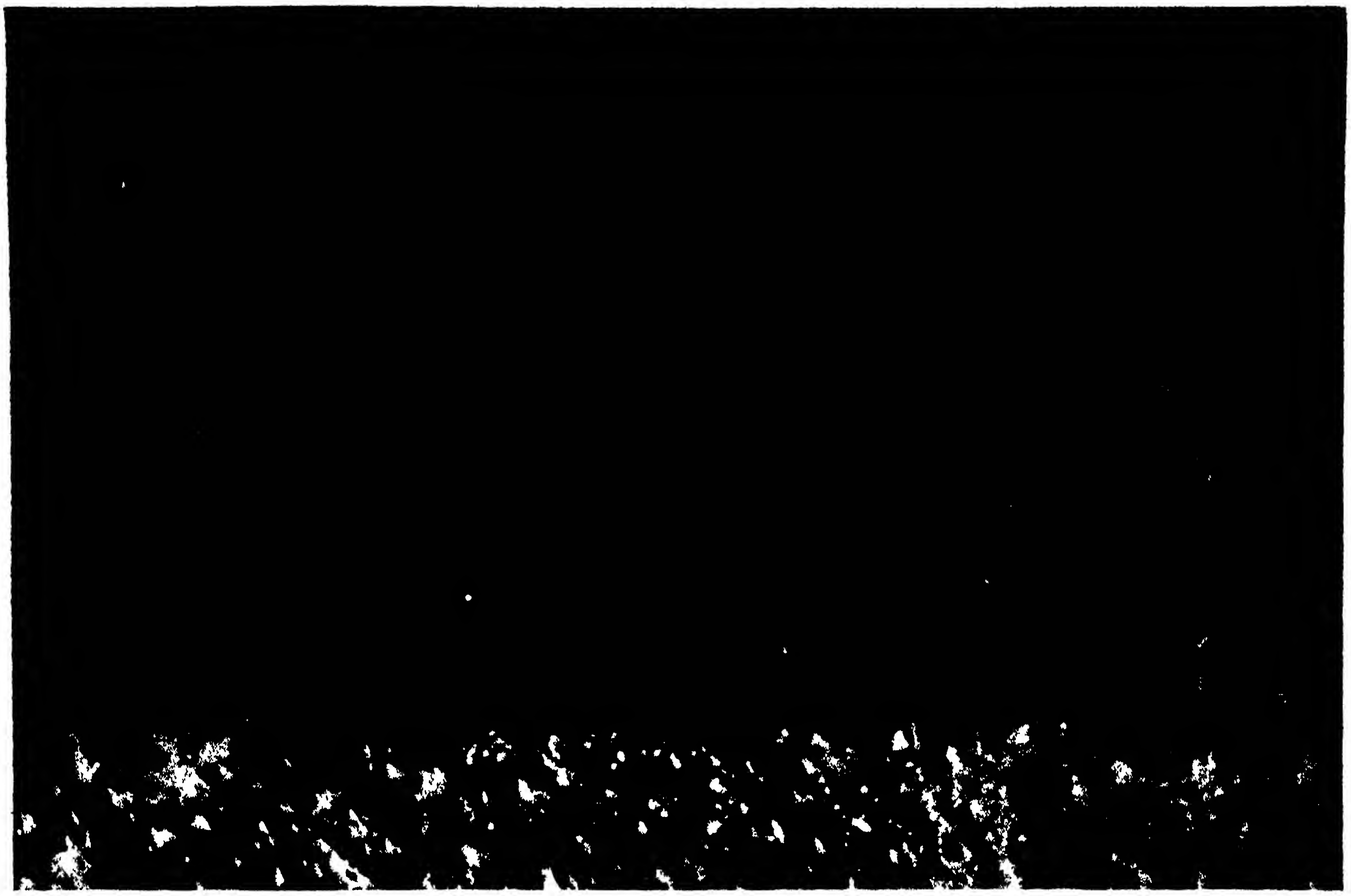
DROP STRIKES the wet soil, carrying tiny particles of it into the air.

On level land the splashing particles of soil tend to bounce back and forth, so there is no net loss of soil from any point on the field. But on a slope the splashes move the soil downhill. Part of this movement is caused by the drops striking glancing blows which kick most of the particles towards the bottom of the slope. Another part will be caused by the fact that soil splashed in the downgrade direction travels farther in the air than that splashed uphill. Many tests have shown that on a 10 per cent slope the downhill movement is about three times the uphill.

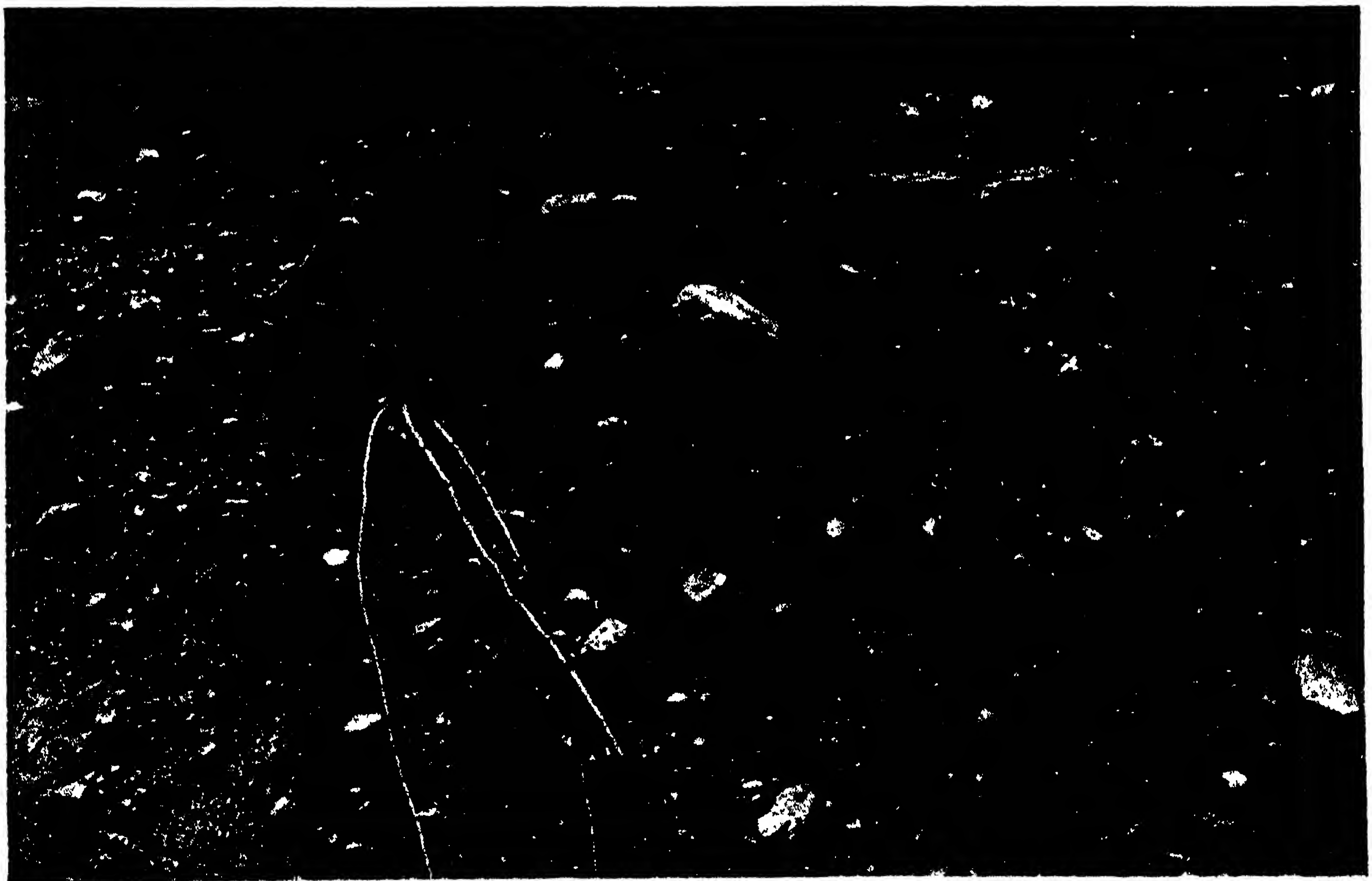
Flowing water on sloping land produces erosion by forming gullies. Regardless of how smooth the surface may be, the washing process, known as scour erosion, always starts by grooving the soil. Scour erosion made the Grand Canyon and carved out our river systems. Gullies make the landscape rugged, so scour process is classed as a land-roughening process.

In contrast, splash erosion removes the sloping topsoil in sheets. It acts as a smoothing and leveling agent. These effects are demonstrated in miniature each time that beating raindrops flatten and level a small sand pile in the yard. It works in about the same way on a hill, bringing material down from the crest and depositing it low on the slope. After a great gully is carved by scour erosion, the splash process slopes the vertical side walls and converts the rough gully to a gently sloping valley. After a series of storms, topsoil scalped from the crest of a slope by raindrop splashes can be found piled lower on the hillside.

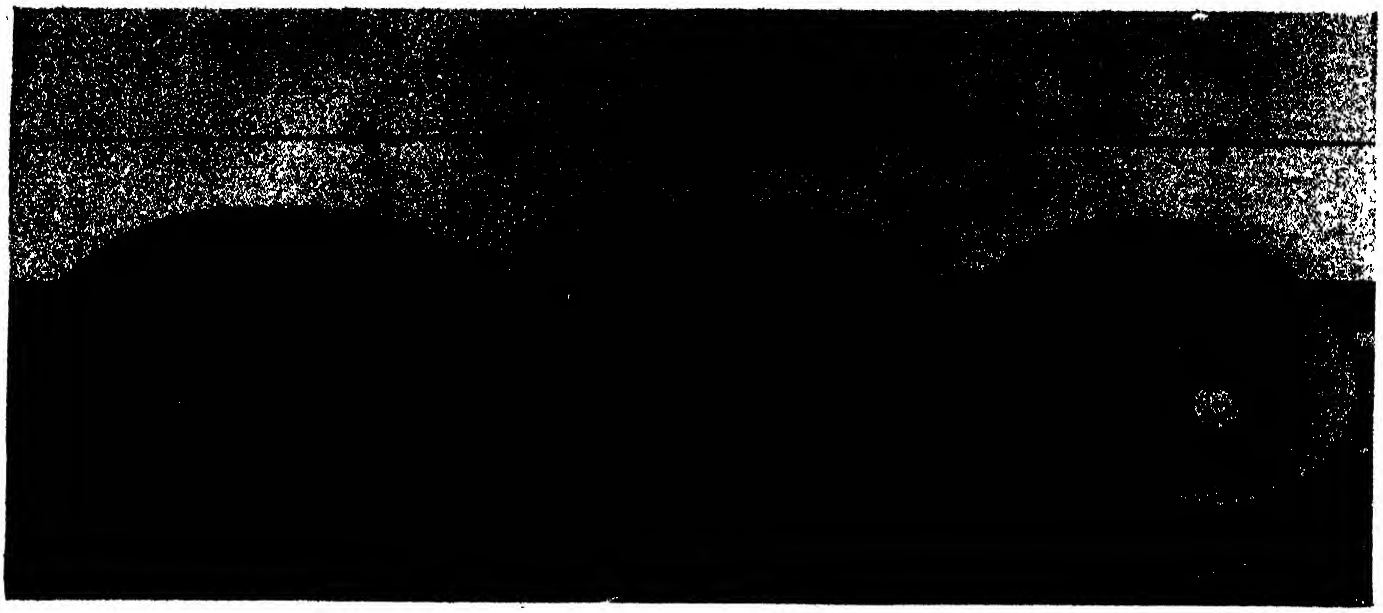
The splash process produces four different types of erosional damage: 1) piling and burying of topsoil; 2) surface sealing; 3) deterioration of the structure of the soil; and 4) the loss of crop nutrients by the process called elutriation. The piling and burying of topsoil is the result of the land-leveling process. Topsoil that is scalped from the crest of a slope slows in movement as it approaches the gentler slope near the bottom of the hill. This causes "telescoping" of the soil; that is, soil from high on the slope overtakes material in motion low on the hillside. The result is that the topsoil piles up in a bank near the bottom of the hill, and this

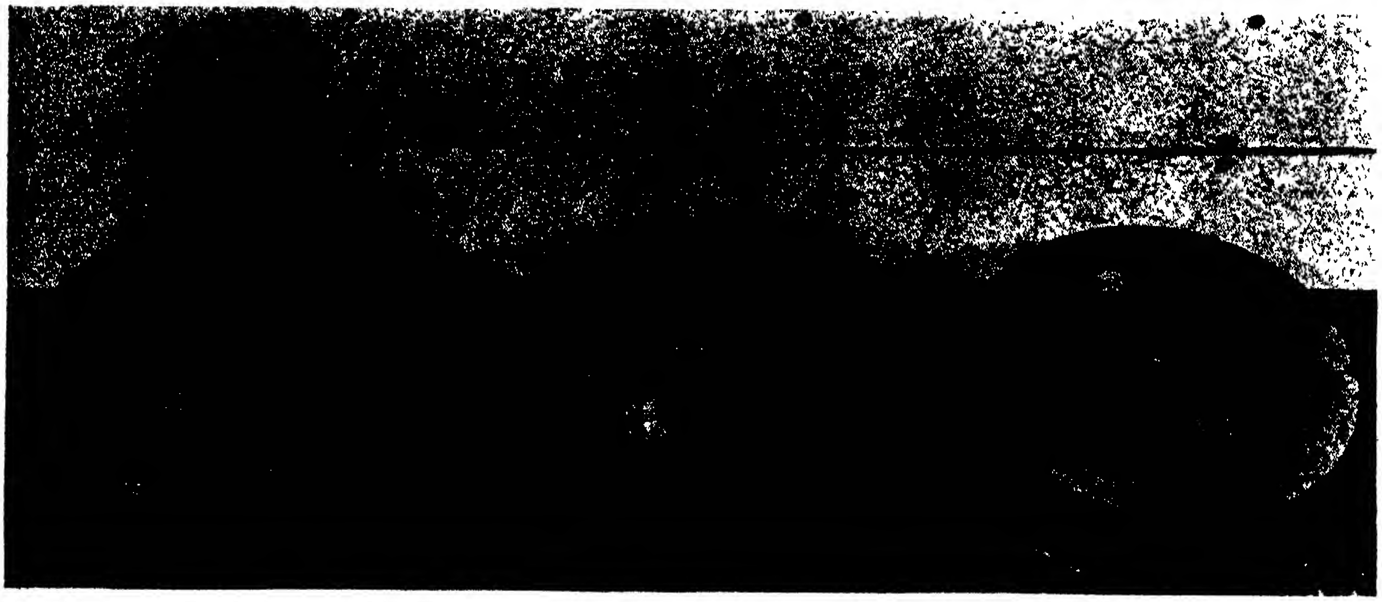


MULTIPLIED EFFECT of many raindrops is illustrated by this photograph. Falling from great height, drops strike the soil and shatter into many smaller drops. These describe a parabola as they arch upward.



CHARACTERISTIC RESULT of raindrop erosion is to splash away a whole layer of unprotected soil. Where the soil is shielded by a stone, a little pedestal remains. The rod at the top of this picture is marked in inches.





EXACT MEASUREMENT of the effect of raindrop erosion is made by putting three pans of soil under a laboratory rain-making machine. Coins are placed on the soil to mark its original level. Top picture shows dry soil. Middle picture was made after 45 seconds of rainfall. Bottom picture was made after one hour and 15 minutes

is later covered with subsoil brought down from near the hilltop.

These changes do not come from a single storm. They are long-time developments. The first striking evidence of the splash process is the appearance of "bald" crests high on the slopes. Farmers have been heard to say that during the month of August they can see a rabbit in a neighbor's cornfield a mile away so long as it stays near the crest of the hill. They used to embarrass conservation experts by asking why all the erosional damage seemed to be at the crests of slopes where there was very little surface flow; the answer, although the experts did not know it, is splash erosion.

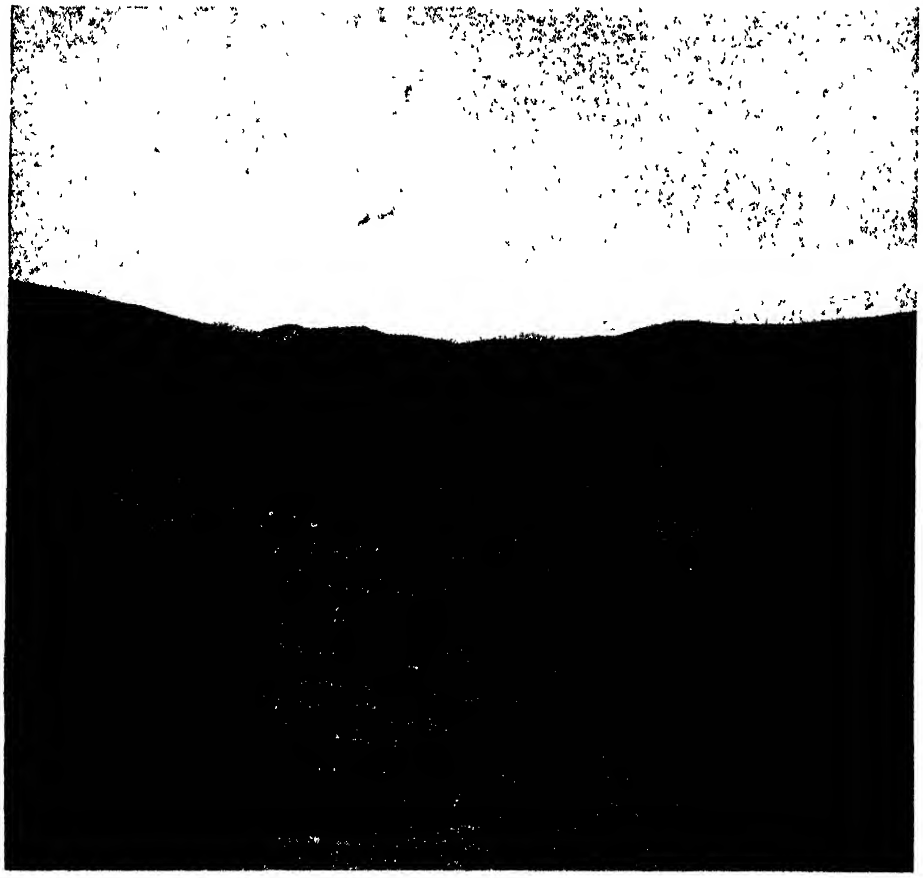
Damage caused by the piling and burying of topsoil is usually many times more important agriculturally than are the tonnage losses that go down the rivers. Data on the amount of soil carried down the Mississippi can be cited in support of this conclusion. The National Encyclopedia, 1935, states that approximately 400 million tons are carried down the great river annually. Expressed in terms of watershed units—and it must be expressed in those terms to determine its significance—this loss amounts to only about one inch of soil removed from the surface of the entire watershed every 300 to 400 years. That amount is not too important agriculturally. Of course, we do not want to lose this soil if we can prevent it. But its loss does not represent the real erosion problem. A loss of one inch of soil every 300 years probably represents something less than 10 per cent of the important damages to a soil by erosion.

SURFACE sealing, the second soil damage on our list, is caused by raindrop splashes puddling the soil and making it practically impervious to water. This point has been proved by experiments. For example, in a field where the soil splash was one ton per acre, the surface sealing was light; the water intake capacity of the soil was 8.5 inches of depth of water per hour. But in a field of the same soil type which had a splash of 33 tons per acre, there was considerable surface sealing and the infiltration capacity dropped from 8.5 inches to 0.96 inch of water per hour.

We have not been accustomed to thinking of surface sealing as an erosional damage. It does not occur where surface soils are made stable against the action of water. But where it does occur there is a host of ill effects associated with it. For one thing, it makes the soil droughty. Droughtiness and the high temperatures associated with it destroy worm life in the soil and curtail a field's productive capacity. For another thing, surface sealing tends to increase flash runoff, and this increases flood hazards. Surface sealing also interferes with aeration of the soil and with the emergence of seedling plants

VERTICAL IMPACT of raindrops does not shift the position of the soil, although it does cause other kinds of damage described in the text of this article. Soil that is lifted into the air is replaced by the effect of nearby drops.

IMPACT AT AN ANGLE can move large quantities of soil downhill. This scalps topsoil from the crest and concentrates it at the bottom of the slope. Later the good soil may be buried by subsoil splashed down from above.



OVERGRAZING of hilly range land leads to splash erosion. Here sparse grass has offered so little protection against raindrops that organic matter has been splashed downhill, leaving soil too poor to support new growth.

ELUTRIATION is a process that robs soil of clay and organic matter. Here camera is pointed upward from shallow depression. White strips between these rows is not water but sand that has been splashed clean by raindrops.

from the seedbed. Effective control of splash erosion could reduce the surface sealing caused by rainstorms by 70 to 90 per cent.

Over a period of years, after surface sealing has been repeated many times, the structure of the soil declines. This occurs when tiny aggregates of soil on the surface are broken up, and when the pores in the soil of the plow sole (the compacted layer of earth at the bottom of the furrow) are plugged. The plugging can be caused by the intake of water that is charged with colloidal and other fine clay fractions. As this material filters through the soil layers it is deposited in the pores. Deposits near the surface may have only a temporary effect, but those in the plow sole produce more lasting results. By retarding the percolation of water into the deeper layers of soil they increase the runoff during wet seasons.

THE STRUCTURE of a soil changes with each change in the tiny soil aggregates. It seems probable that our failure to understand splash erosion has caused us to develop misconceptions about problems of soil aggregation and structure. Organically bound soil aggregates are developed through natural processes as organic matter is decomposed in mineral soils. They are destroyed in many ways. Principal among these seem to be the depletion of organic matter and the direct breakdown of the aggregates by physical forces. The splash erosion process is one of the chief agents affecting both of these: the raindrop impacts break down many aggregates and this releases organic matter that was bound in the aggregates, permitting the organic material to be floated from the field.

It is through aggregate breakdown that many field soils are made highly transportable. Consider, for example, a single aggregate made up of many thousand clay particles, several hundred silt fractions and half a dozen sand grains. In addition there may be some humus and some fragments of plant residues. So long as these materials remain bound together in a stable aggregate they are not easily washed away. But as soon as the splash process breaks up the aggregate, the clay and the organic matter become highly transportable and may be floated away in continuous suspension. The silt fractions, which are less transportable, may be dragged and rolled along by intermittent stages, with their movements being speeded each time a raindrop agitates the water that is in contact with them. The sand grains are the least transportable, and if the field slopes are gentle there may be no appreciable net loss of sand. Over a period of years everything but the sand will be carried away.

This process, called elutriation, can be very destructive in sandy soils, though it is of less importance on loams and clays. Uncontrolled elutriation on gently

sloping, sandy land, besides rendering the soil deficient in crop nutrients, organic matter and clay, also destroys its water-holding capacity. Some agricultural soils in this country which once were fertile have been elutriated to such an extent that they now resemble the sands of a beach.

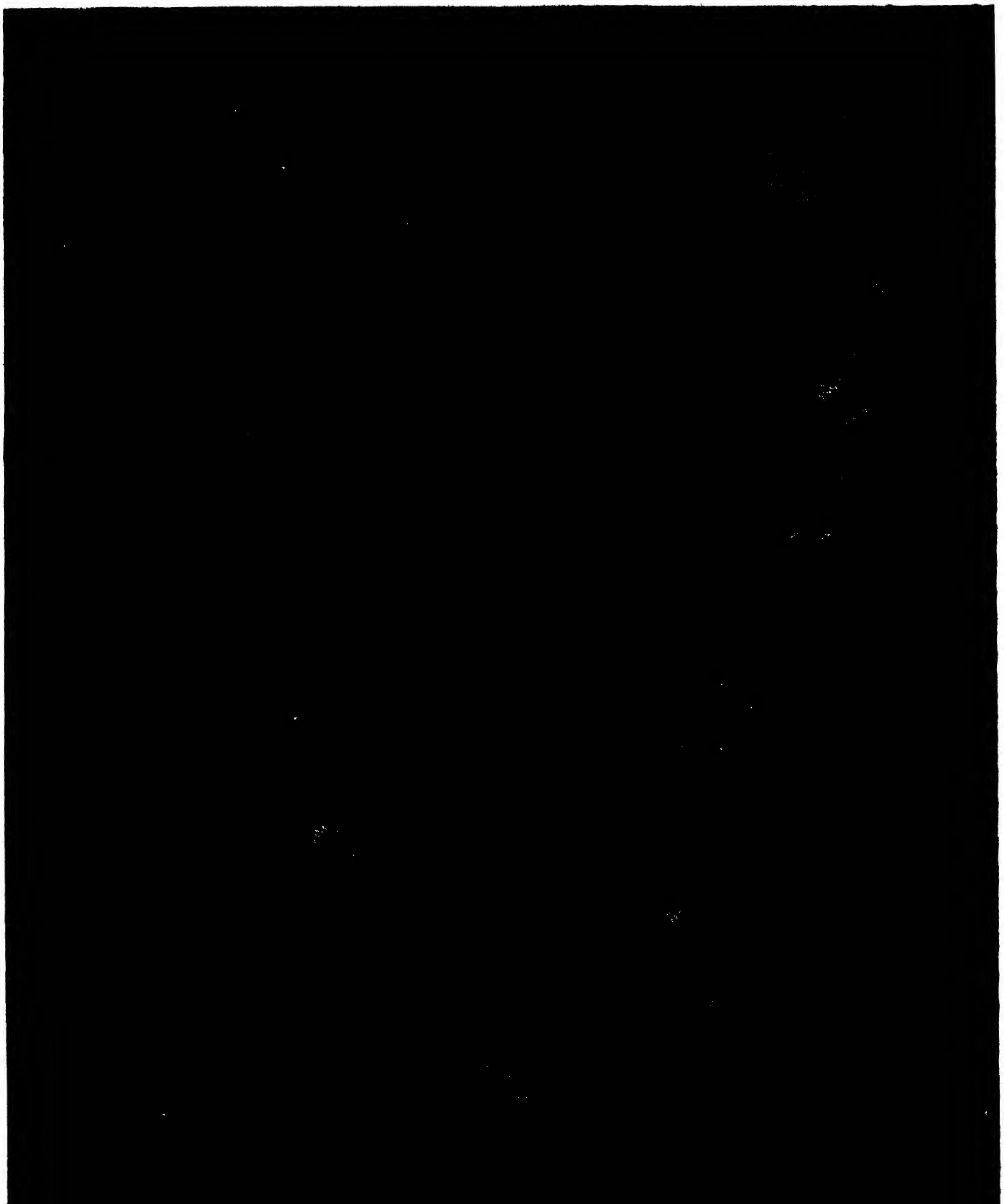
WHAT can be done about it? There is only one way to control splash erosion, and that is by protecting the soil against the impact of raindrops. As one man remarked after hearing an account of the phenomenon: "Agriculture needs a new umbrella." There is no better way of putting it. The greatest opportunities in soil and water conservation lie in developing the umbrella. It must be a special kind of umbrella which de-energizes the falling raindrops, reducing their impact on the soil. Such an umbrella can be provided by making fuller use of growing crops and better use of crop residues and mulches. Terracing and contouring practices that are effective in reducing scour erosion are at best only palliatives in checking splash erosion. They do not protect the soil against the impact of raindrops. This does not mean that we should do less terracing and contouring. Quite the contrary, we probably should employ these practices more than we do at present. I believe, however, that we have a much greater need for a well-developed cover program that will check the splash of soil. Stubble mulching, the method of tillage which leaves crop residues on top of the soil, is an excellent means of protecting the surface against splashing. The development of faster-growing plants also would provide more effective canopies for our cropped fields.

How much cover does it take to protect the soil against raindrops? The answer depends on the type and condition of soil. Here are the results from a piece of range land. On a section covered with 650 pounds of forage and litter per acre, the soil splash was 28 tons per acre. On the same soil, but with 4,300 pounds of forage and litter per acre, the soil splash was only one ton per acre. The amount of cover needed depends on the extent of each type of damage that may be caused by rain splashes on the particular soil involved.

The differences in erosion caused by splashing raindrops and by flowing surface water have not been well understood. A full knowledge of these differences is fundamental to an understanding of erosion problems. Studies made since the discovery of splash erosion have indicated that soil splash launches a chain of damaging processes, and that these can be prevented only by checking the falling raindrops before they strike the soil.

W. D. Ellison is a soil conservationist with the U.S. Navy and the discoverer of raindrop erosion.

PROTECTION against raindrop erosion is given by leafy plants. These absorb impact of the drops and allow water to trickle down to the soil. Leaving crop residues on the ground also offers protection against effect of drops.



BACTERIA UNDER ATTACK by a swarm of bacterial viruses are shown by the electron microscope. The viruses, which are of the strain T4 described in this article, attach themselves to bacteria and sometimes push inside them. There the viruses reproduce until the bacterium bursts, liberating an entire new generation of viruses.

BACTERIAL VIRUSES AND SEX

Some fascinating experiments have demonstrated that the tiny organisms which prey on bacteria employ a primitive kind of sexual reproduction

by Max and Mary Bruce Delbrück

TWO YEARS AGO, at a summer symposium in Cold Spring Harbor, N.Y., experiments were presented which showed that bacteria, and even some viruses that live on bacteria, apparently have a method of sexual reproduction. This finding was a considerable surprise. Up to that time it had been generally supposed that the simple one-celled bacteria had no sex and that they multiplied simply by splitting in two: the method of reproduction of the still more rudimentary bacterial viruses was entirely unknown. The simplest organisms previously known to have a sexual mode of reproduction were the molds, yeasts and paramecia. Indeed, the recognition of sex even in those organisms was less than 20 years old.

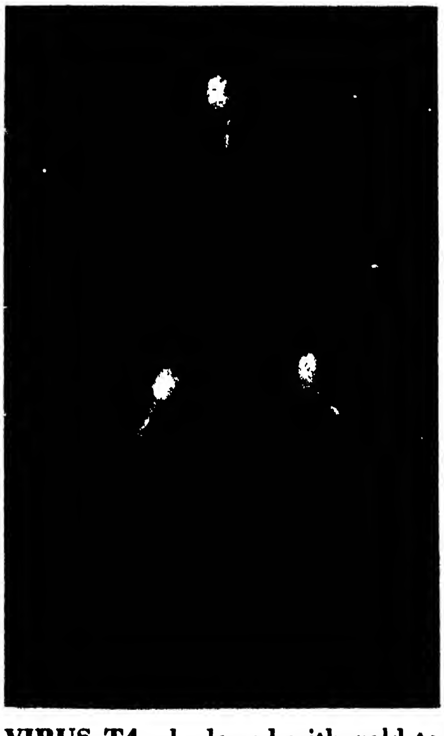
Sex was once thought to be the exclusive possession of life's higher forms. Yet as biologists have looked more carefully down the line, simpler and simpler forms have been found to be possessed of it. Now, among the viruses, we are searching for it at the lowest known level of life.

Since the Cold Spring Harbor symposium, this research has been pushed further, and some rather remarkable facts have been uncovered. This article will discuss a group of the viruses which are parasites of bacteria, and particularly will go into what has been learned recently concerning their reproduction.

Sexual reproduction is the coming together and exchanging of character factors of two parents in the making of a new individual. Aside from its other aspects, sex has a special interest for biologists as a highly useful and indeed almost necessary device for an organism to survive in the competitive evolutionary scheme of life. Plant and animal species, to avoid extinction in the changing environments of geologic time, evolve by utilizing mutations (changes in the basic hereditary material) which enable them better to adapt themselves to their environment. These mutations turn up spontaneously and spread through the population by the convenient means of sexual reproduction.

Mutations are assorted and combined anew in every generation. Thus species that reproduce sexually always have in store a vast array of new types, some of which may be adapted to a changed environment and can become the parents of the next link in the evolutionary chain. This is the evolutionary advantage of sex.

It is logical, therefore, to look for sex in every known form of life. It was with great caution, however, that the discovery of sex in the simplest organisms was reported two years ago. E. L. Tatum and J. Lederberg of Yale University told of experiments in which they had found bacteria which seemed to combine certain traits of two parental strains that had been mixed. Similar findings with respect to the viruses that attack bacteria were reported by A. D. Hershey of Washington University, and by W. T. Bailey, Jr. and M. Delbrück at Vanderbilt University.



VIRUS T4, shadowed with gold to make a specimen for the electron microscope, has shape of a tadpole.

The bacterial virus is a very small organism which enters a bacterium, reproduces itself and eventually destroys its host. From the latter a generation of new viruses then emerges. The virus thus "infects" a bacterium, even as plant and animal viruses infect plants and animals. Bacterial viruses were first discovered 30 years ago by the French bacteriologist F. D'Herelle, who noticed that the bacteria growing in some of his test tubes mysteriously dissolved. After experimentation D'Herelle concluded that their dissolution was due to some agent much smaller than a bacterium, and that this agent grew at the expense of bacteria. He called the agents that had destroyed the bacteria "bacteriophages" (bacteria-eaters); the same organisms are now often called bacterial viruses.

For many years thereafter bacteriologists and medical men were sure that bacterial viruses existed. The viruses were even measured, isolated and grouped, although they were never actually seen. Bacterial viruses are too small to be seen under the most powerful microscope of the conventional type; they have been made visible only recently by new types of microscopes.

D'Herelle's discovery raised the great expectation that bacterial viruses might be used as "agents of infectious health" to destroy the bacteria that caused human and animal diseases. It was the hope of early research workers that a population infected by a bacterial epidemic could be cured by infecting it with the virus inimical to that bacterium. Their hope has not been realized, but the bacterial viruses remain a subject of keen interest—for good and sufficient reasons.

Viruses seem to lie on that uncertain and perhaps unreal borderline between life and non-life. The uncertainty about this boundary line is both very old and very new. In ancient times all nature was supposed to be animate. Spirits dwelt in stones as well as in animals, and as recently as a few centuries ago the spontaneous generation of complex living organisms from mud was a matter of universal belief. The advance of the scientific method has taught us that there is an enormous difference between the living and

inorganic worlds. During the development of classical biology in the 19th century, there arose two great generalizations: 1) the theory of evolution, and 2) the cell theory. The theory of evolution proclaims the relatedness of all living things; the cell theory sets forth a universal principle of construction for them. Both of these generalizations unified biology and distinguished it from the study of the inorganic world.

In our generation, however, the pendulum has begun to swing the other way. The great refinement of scientific technique has pushed the limit of observation beyond the point where it had stood for about 100 years, namely, at the resolving power of the light microscope. With this advance has come the recognition of the existence of many things below cellular size which do not fit into the established categories of life or non-life. Of these the viruses have become the most controversial. To learn all we can about them becomes, then, even more intriguing than the original idea that bacterial viruses might be useful in medicine.

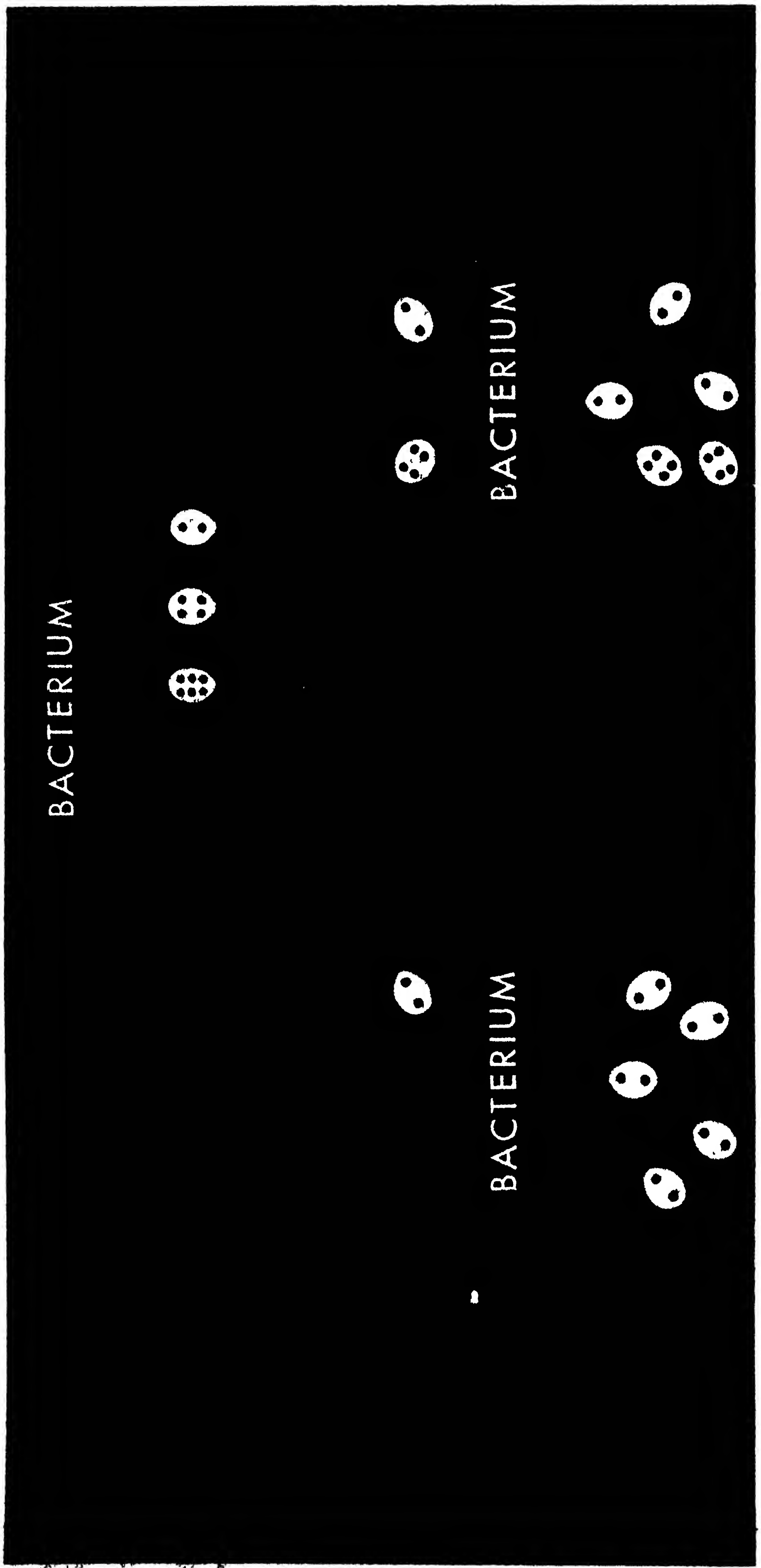
Bacteria-eating viruses are common, and where bacteria exist in the natural state, viruses capable of destroying them almost always can be found. Outside of the bacterium, the virus seems dead. But it does not die; it lies quiescent and functionless until a bacterium presents itself. The virus then attaches itself firmly to the bacterium. Many viruses may cling to a single bacterium, but only one needs to enter the cell to begin a cycle of viral reproduction. Once within the host, the virus quickly comes to life and multiplies prodigiously. How it grows from the one or more particles that are known to enter the cell to the several hundred that burst from the suddenly ruptured host is a secret still closely guarded within the walls of the bacterium.

The guinea pigs of bacterial virus genetics have been seven different viruses which all attack the same bacterium. Some of these viruses, which we shall speak of as T1, T2 and so forth, are surprisingly complex in form and behavior.

The viruses that were first made visible by the electron microscope in 1941 were revealed to be spermlike forms. Some were seen lying free, others were clinging to the exterior of a bacterium. Other pictures revealed the bacterium with new viruses streaming from a hole ripped in its cell wall.

The seven viruses do not all look alike. In appearance they fall into four categories. The members of one family, consisting of T2, T4 and T6, look like tadpoles, with dark forms visible within their bodies. T5 has a round, solid body and a tail. T1 is similar to T5, but smaller. T3 and T7 are the smallest, with spherical bodies and no visible tail.

The viruses which look alike are related in several other respects, and the way



EXPERIMENTAL ORGANISMS of the research discussed in this article are seven bacterial viruses that attack the same species of bacterium.

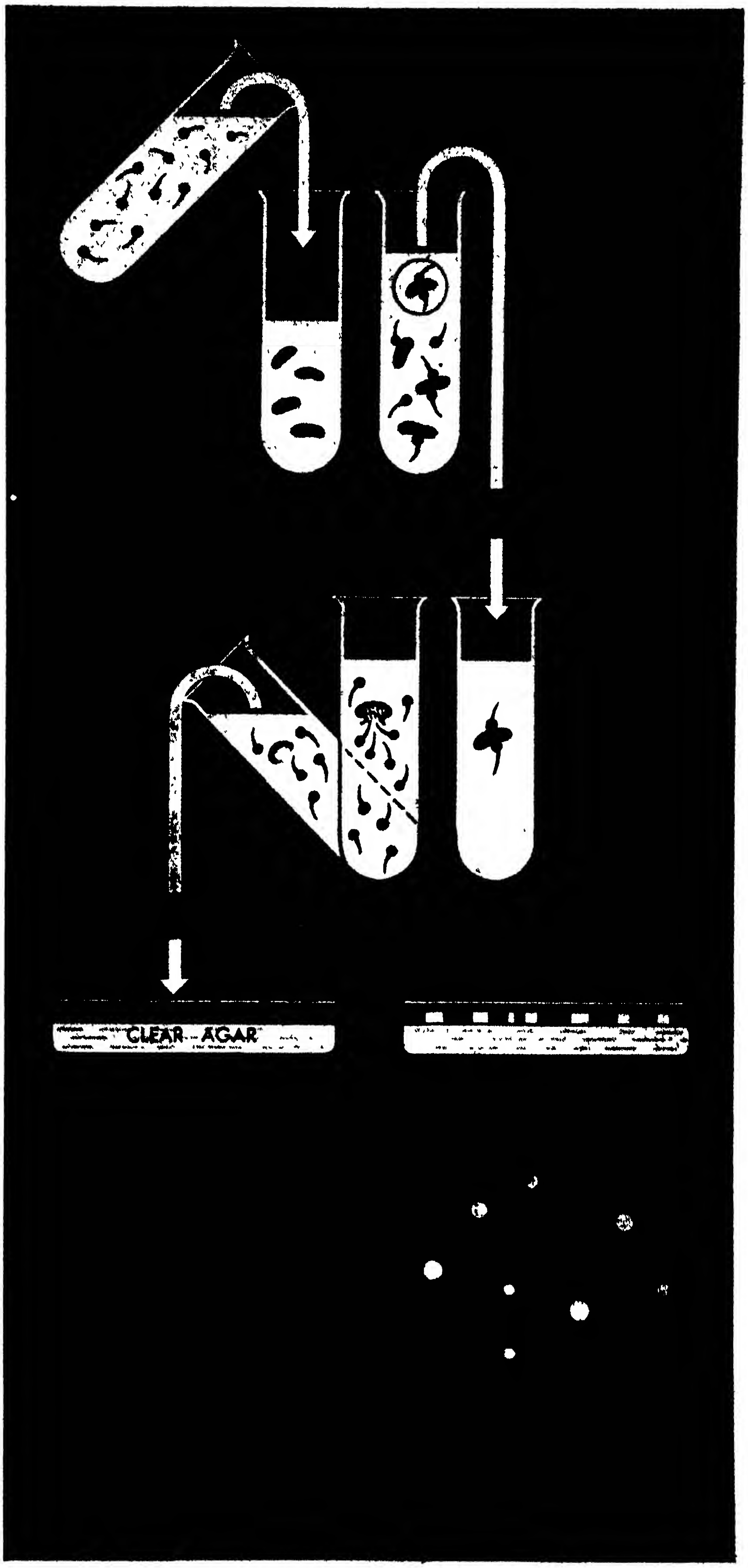
they behave as a family is illustrated by a very curious phenomenon. When two viruses which are not related happen to attach themselves to the same bacterium, one successfully enters the bacterium and multiplies, but the other perishes without leaving any offspring. If the two viruses seeking the same bacterial home are related, however, both enter and reproduce. This rule has certain exceptions and certain special modifications, depending on the degree of relatedness between the contending viruses; as among human beings, the restriction of real estate among the viruses has subtle points.

One might wonder how the biologist can learn anything about the behavior of organisms so small that he generally cannot see them. The answer is that bacterial viruses make themselves known by the bacteria they destroy, as a small boy announces his presence when a piece of cake disappears. Much of what we know about the viruses is based on the following experiment, which requires only modest equipment and can be completed in less than a day.

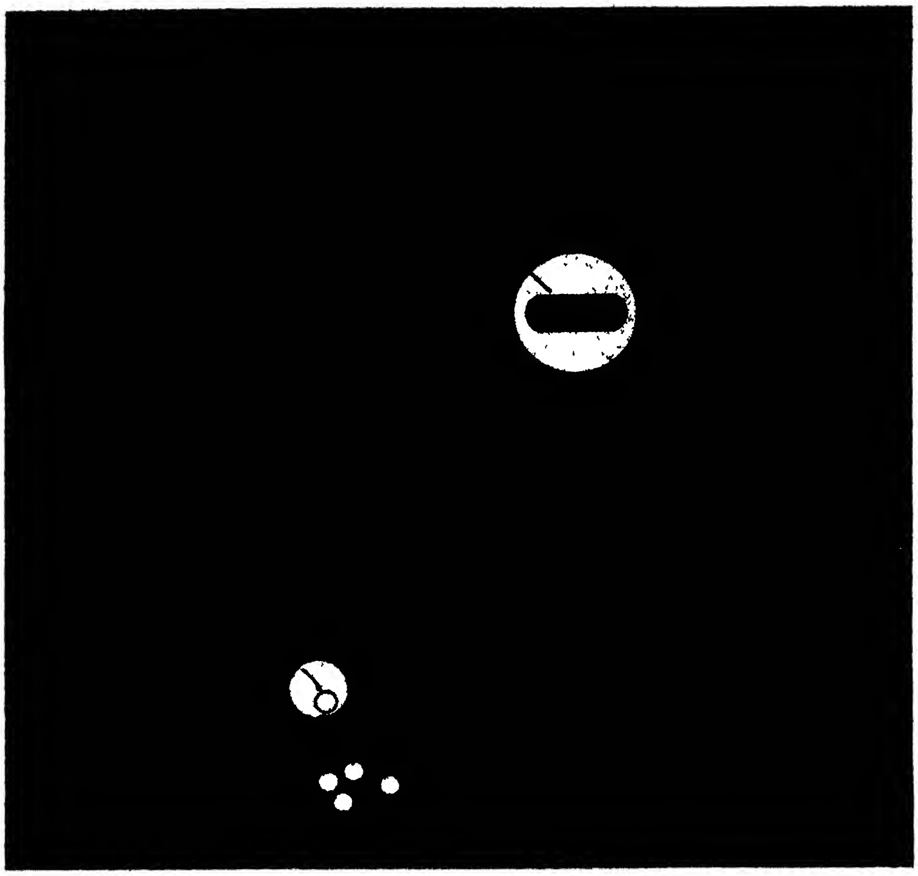
Bacteria first are grown in a test tube of liquid meat broth. Enough viruses of one type are added to the test tube so that at least one virus is attached to each bacterium. After a certain period (between 13 and 40 minutes, depending on the virus, but strictly on the dot for any particular type), the bacterium bursts, liberating large numbers of viruses. At the moment when the bacteria are destroyed, the test tube, which was cloudy while the bacteria were growing, becomes limpid. Observed under the microscope, the bacteria suddenly fade out.

Before the bacteria burst, however, part of the liquid is taken from the test tube and diluted. From this diluted liquid the experimenter takes a small sample expected to contain only a single infected bacterium. When this bacterium has liberated its several hundred viruses into a liquid medium in a test tube, the liquid is poured on a plate covered with a layer of live bacteria. Each virus deposited on the plate will start attacking the bacterium on which it rests. Each of the offspring of the virus, in turn, will attack the nearest bacterium. Successive generations of offspring from the one original virus will spread out in a circle, attacking bacteria until after a few hours a small round clearing becomes visible to the naked eye. The number of such clearings, or "colonies," formed on the plate is a count, therefore, of the number of viruses liberated by the original infected bacterium.

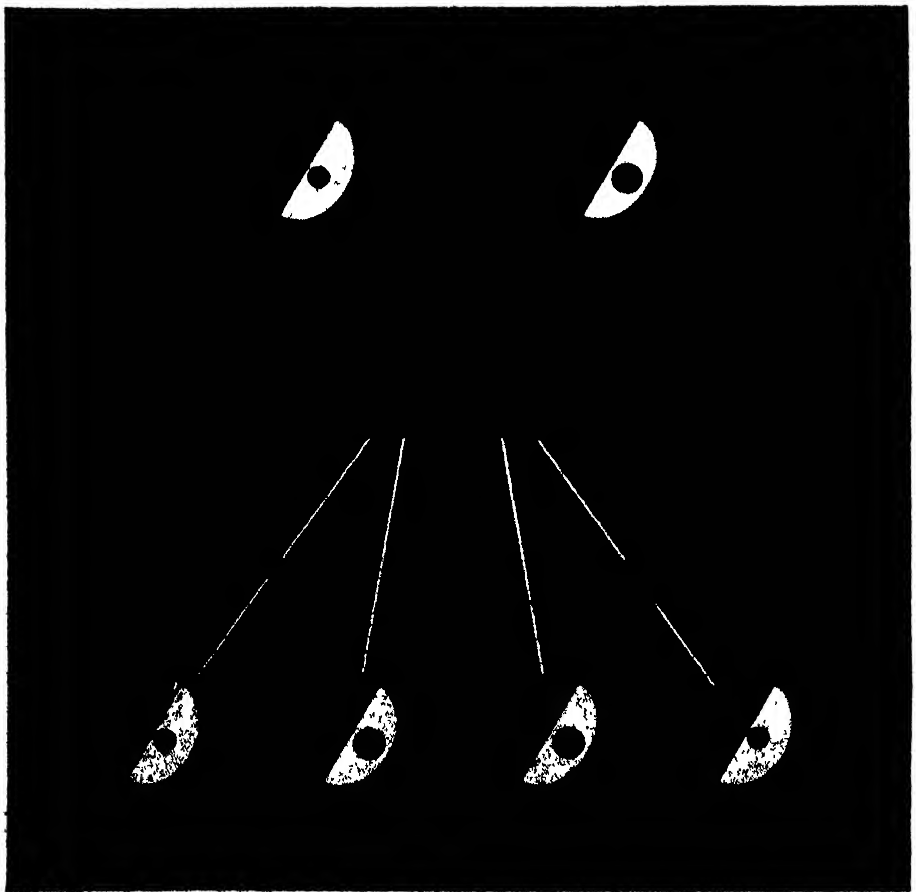
The union of the virus and its bacterium takes place under rather complicated and specific conditions which are not well understood. Of the life of the virus inside the bacterial host, still less can be divined. Does the virus multiply by one individual producing another, by simple splitting, or by some other process? What specific elements of nutrition are necessary for virus



EXPERIMENTAL TECHNIQUE that is used in bacterial virus research is outlined in this drawing. The equipment required is remarkably simple.



MUTATION is the mechanism that enables bacteria and viruses and all other living things to adapt themselves to changing environmental conditions.



EXCHANGE of virus characteristics is form of sexual reproduction. Here characteristics are type of bacterium attacked and the size of the colony.

reproduction? Is it possible to break open the cell before it would normally burst and from the contents at this intermediate stage learn something of the process of multiplication? What causes the violent disruption and dissolution of a bacterium?

Although we cannot fully answer these questions, it has nevertheless been possible to wrest some remarkable secrets from the viruses. We have learned something about the way in which they transmit characteristics and survive from generation to generation. One method of investigation has been to study the fashion in which viruses are able to meet emergencies in their environment. For example, when viruses are mixed with bacteria, most of the bacteria are destroyed. One in perhaps 100 million bacteria, however, will mutate to a form that is resistant to the virus, thus establishing a line of defense for its species. The virus, on the other hand, is capable of launching a new attack by mutating to a form which can destroy the resistant bacteria.

ALL kinds of mutations, many of them easy to recognize, turn up among the viruses. Some produce variant types of colonies on the bacterial plate; they may create fuzzy clearings instead of sharp-edged ones, or large clearings instead of small round ones This kind of virus mutation was discovered in 1933 by I. N. Asheshov (who now heads a research project on bacterial viruses at the New York Botanical Garden) during his studies of anti-cholera vibris viruses in India Other breeds of viruses have been found which need some particular substance, such as a vitamin or calcium, to become capable of attaching themselves to the bacterium. T. F. Anderson, of the Johnson Foundation for Medical Research at the University of Pennsylvania, opened up a totally unexpected new angle in viral research when he discovered that viruses T4 and T6 will not attack a bacterium in a medium lacking a simple organic compound called 1-tryptophane.

The discovery that bacterial viruses have a sexual form of reproduction came about in the following way. M. Delbrück and W. J. Bailey, Jr. were working with viruses T2 and T4r (a mutant of T4), which are relatives that can reproduce in the same bacterium of strain B. Each has two distinguishing characteristics: T2 produces a small colony and can destroy a mutant strain of bacteria called A; T4r produces a large colony and can destroy a mutant strain of bacteria called C. When T2 and T4r were added to a bacterium, viruses of both these parent types were released upon burst, as expected. But in addition two new types of virus came out, with their characteristics switched! One of the new types produced a large colony and destroyed bacterium A; the other produced a small colony and destroyed bacterium C. Obviously the parents had got together and exchanged

something. The number of individuals of these new forms coming from a single bacterium varied, but the maximum number found was about 30 per cent of the total yield.

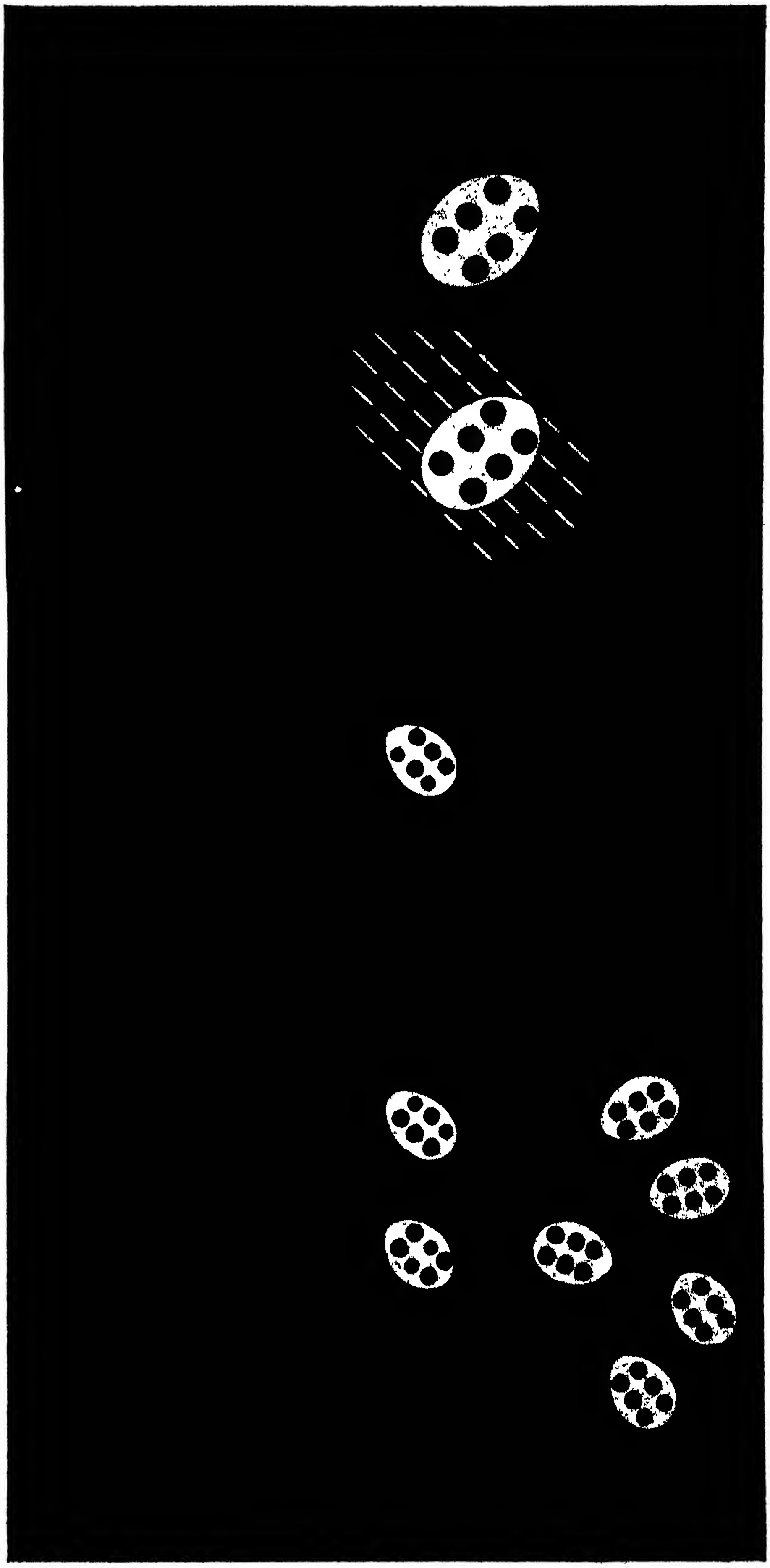
The most surprising discovery of all, however, was made by S. E. Luria of Indiana University. It came about as a sequel to an accidental observation in our laboratory at Vanderbilt University. When a virus that has been "killed" by exposure to ultraviolet light is added to a bacterium, the bacterium is destroyed but no new viruses issue from it. In one such experiment, Bailey irradiated viruses long enough so that most, but not quite all, of them were killed. He then transferred some samples, as usual, to a bacteria-covered plate. He wanted to determine the number of survivors, and expected to find less than 100 virus colonies on the plate. Instead, the next morning he found thousands of colonies! Puzzled, Bailey repeated the experiment, with the same result. The supposedly dead viruses had in some way come to life.

Later, at Indiana, Luria took this problem up seriously. He discovered a curious fact: although a bacterium infected with only one "killed" virus dies and yields nothing, a bacterium infected with two or more "killed" viruses bursts and yields several hundred new viruses. Luria therefore assumed that inside a bacterium two or more "killed" viruses (or perhaps we had now better call them mortally damaged) can pool their undamaged parts to make whole individuals capable of reproducing themselves and of escaping from the bacterium. He estimated that each virus of the T2, T4 or T6 type has about 20 vital units. Assume that each time a virus is shot at, or exposed to ultraviolet light, one vital unit is knocked out. If there are two viruses, each of which has been shot at four times, there is a good chance that the same vital unit has not been hit in both. The remaining units then seem to have a way of combining and forming effective individuals.

This "revival of the dead," as we might call it, which indicates some substitution of vital material, is interrelated with the previously mentioned exchange of character traits in viruses, a phenomenon which has been explored very successfully by A. D. Hershey at Washington University.

Gradually the study of these two phenomena should reveal something more of the way in which one virus produces another and—the most ambitious hope—even something of the simple facts of life. Here, as far as mind and imagination and skill can reach, is a vast region of the very small that is open for exploration.

Max Delbrück is professor of biology at the California Institute of Technology. Mary Bruce Delbrück is his wife.



DAMAGE to viruses by ultraviolet rays (*second drawing from top*) is added proof that they exchange characteristics. Damaged viruses pool resources.

GULLIVER WAS A BAD BIOLOGIST

Jonathan Swift's famous fantasy gives the modern biologist an opportunity to reflect upon the way living things are tailored to their environment

by Florence Moog

When Jonathan Swift's Captain Lemuel Gulliver first published his account of his remarkable adventures in undiscovered Pacific lands, his contemporaries appear to have responded with some skepticism. Their reluctance to believe in six-inch men, floating islands and educated horses is mirrored in Gulliver's overprotesting preface to the second edition of his now-famous *Travels.* Whether his contemporaries were impressed by his insistence that from consorting with the Houyhnhnms he had been able to rid himself of "that infernal habit of lying" common to Yahoos is doubtful. In any case the two centuries that have elapsed since then have seen the growth of a body of knowledge by which the improbability of the creatures of Gulliver-land may be translated into impossibility.

Much of this knowledge has been the direct concern of biologists, those present-day kindred of Gulliver's academicians of Lagado. Indeed, for a student of comparative biology Gulliver's book may serve as an unpremeditated textbook on biological absurdities and, as a corollary, on the nicety with which all living organisms are tailored to the physical conditions of their existence.

The most unlikely of Gulliver's inventions, the 60-foot Brobdingnagians, actually could have been explained away, long before the biologists got around to it, by a principle of physics first developed by Galileo almost 100 years before Gulliver's odyssey appeared. According to the principle of dimensional analysis, the weight of a system increases as the cube of its linear dimensions. The principle seems to have been well known to Gulliver's Lilliputians, for it was the means they used in calculating that Gulliver equaled 1.728 Lilliputians. Since six-foot Gulliver was 12 times as tall as a six-inch Lilliputian, they computed that he weighed as much as one Lilliputian times 12^3 ($12 \times 12 \times 12 = 1{,}728$). The weight of a 60-foot Brobdingnagian may be similarly calculated as 10^3 times that of a six-foot man, let us say 180 pounds times 1,000, which is 180,000 pounds or 90 tons!

No wonder Gulliver neglected to mention the Brobdingnagians' weight! No very acute insight into structural principles is needed to see that such a tremendous bulk could not be borne in a frame of human proportions. The upper limit of weight which a body built on the human pattern will carry is perhaps no more than the 500 pounds reached by an occasional eight- or nine-foot rarity. A greater bulk would necessitate a truly ponderous skeleton. The long bones of the legs would be shortened relatively to prevent their bending under their great burden; the head would become comparatively small, for reasons we shall look into later, but its larger absolute size would entail shortening and thickening of the neck; much of the increased weight would be taken up in the trunk, for the internal organs would have to undergo relative enlargement to provide adequate power to move the huge machine.

GIANT Brobdingnagians, here talking with tiny Gulliver, can be shown to be an engineering impossibility.

Examination of a few hoofed mammals will neatly illustrate this adaptation of form to mass. A gazelle of 150 pounds, for example, has a rather long neck on which is mounted a head which, though large in relation to the slight body, is small as tall animals' heads go; the heavier head of a 1,200-pound horse, though smaller in proportion to body size, requires a shorter and more powerful neck to support it; while the great head of a five-ton elephant, though not large in relation to the gargantuan body, is too heavy to afford the luxury of any noticeable neck at all. Similarly, the slender legs of the gazelle may constitute two thirds of the height at the shoulder, whereas the sturdy limbs of a plow horse are only about half the height, and the pillarlike props of the elephant not much more than one-third. The mind shrinks from picturing the broad-beamed corpulence of a Brobdingnagian. In fact we need no more than the zoo-keepers' rule that once around the forefoot of an elephant is half the height of the body to make it clear that the delicacy of the feminine ankle must have been a matter of no interest in Brobdingnag.

We need have no fear of ever finding such a neckless, short-legged monster peering into our sixth-story windows, for no 90-ton animal could ever walk on dry land. Certainly such bulk could not walk on the arched structure of the human foot, which is too ready to flatten under a little additional strain in normal-sized people. A flesh-and-bone foot ten times longer than the normal human one and a thousand times heavier would have as much difficulty supporting even itself as would a covered bridge enlarged to span the Mississippi. Mount 90 tons on it and such a foot would require bones of steel bound by ligaments of wire cable.

The limiting strength of living tissues, especially muscle and connective tissues, is probably the reason why nature, in millions of years of experimentation, only

once succeeded in designing a land animal even half as ponderous as a Brobdingnagian; this animal was a now long-extinct rhinoceros. The tremendous dinosaurs, in their vain attempt to make muscles outweigh brains, may have approached a Brobdingnagian weight, but they were not strictly land animals; they lived in swamps, sharing their burden with the buoyant water as the whale does today.

IF the Brobdingnagians were too big to exist, the mouse-sized Lilliputians were too small to be human. So long as the laws of physics and chemistry obtain, living cells cannot vary much in size. Hence large animals must be built of more cells than small ones. In many organs cell number is not important, but the brain is in this respect like a telephone system (*see page 14*): a small private telephone system is of limited usefulness compared with one in which a great number of individual units, with their connecting wires and central switchboard equipment, make it possible for any person or institution to get in quick touch with any other. The human cortex, which is the portion of the brain that receives sensory information and deals intelligently with it, has an estimated 14 billion cells. On the inconceivably numerous interconnections which keep this vast assemblage of units in touch with one another depend the adaptability and educability of the human being. Were this tremendous number of cortical cells to be much reduced, the apparently inexhaustible capacity of good human minds for learning, remembering, perceiving and thinking would wither; it would shrink perhaps to the low level of defectives in whom the brain is cramped by a "pinhead" skull or by the abnormal presence of fluid in the cranium.

Now if we allow to a Lilliputian nerve cells as large as those of a mouse (which have about one-fourth the volume of human nerve cells), his tiny cranium could accommodate something like 35 million cortical cells—a large number indeed, but only a small fraction of what even a chimpanzee has at his disposal. On such a small allotment of intellectual equipment the Lilliputians could never have devised their delightful court routine, which yielded nothing in intricacy or absurdity to the best that Augustan England had to offer.

The Lilliputians also would have needed disproportionately large heads to carry useful eyes. Anyone who has ever quizzically scanned an elephant, trying to determine just where the enormous beast has its diminutive eye, must realize that eye size varies far less than body size. A small animal seems to have too much eye in relation to the expanse of its head, and this is because the limits of eye magnitude are dictated by the physical properties of light, which must enter through a pupil not too small, and must impinge on a sufficient number of seeing elements—the rod- and cone-shaped cells of the retina

TINY Lilliputians have various logical drawbacks, among them the difficulty of constructing an eye that would fit their small heads. The drawings on this and the opposite page are from a 1768 edition of the works of Swift.

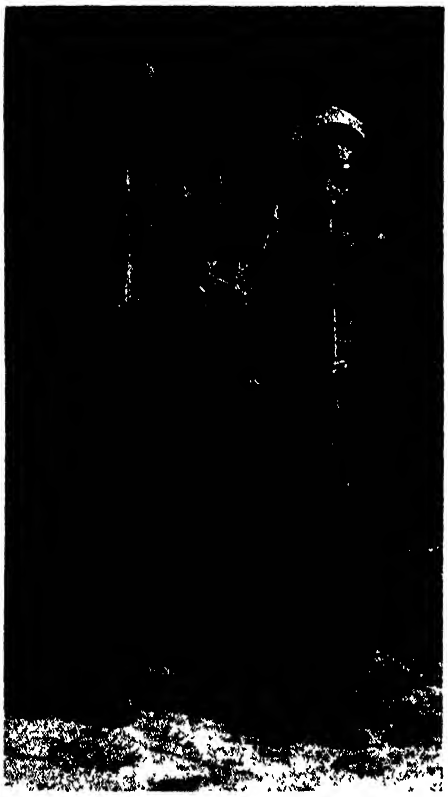
—of almost invariable size. The eye is thus in a sense a doorway which must admit a certain minimal amount of light, but need not admit much more; just as an architectural doorway, whether of a cottage or a mansion, must be big enough to admit a man, but need not be much bigger.

So if a Lilliputian had had a head large enough to hold an intelligent brain and serviceable eyes, he would have needed a heftier body to hold up the head. The smallest known human race, the African pygmies, stand four and a half feet high. Even the tiniest human dwarfs, who never achieve quite correct physical proportions, are almost always more than two feet tall.

But overlooking for the moment the matter of unaccountable intelligence in unreasonably small heads, let us take note of another Lilliputian character that casts doubt on their creator's veracity. The voices of the miniature people, we read, were shrill—a shrewd guess, but not shrewd enough. Had Gulliver considered the difference in pitch which a small difference in size makes among the members of the viol family, he might have been more cautious about assigning any audibility to the Lilliputian voice. Pitch, measured in cycles per second, varies inversely with the square of the linear dimensions of the vibrating surface. So the vocal cords of a six-inch human being would vibrate 144 times faster than those of a six-footer; allowing our voices to center comfortably at 256 cycles per second (middle C), the small voice would vibrate at about 37,000 cycles per second—more than seven octaves higher! This would not inconvenience a Lilliputian, whose ears would probably have a sensitivity proportioned to his voice, but Gulliver's ears must have been practically deaf to sound of more than 10,000 cycles per second. Even had the captain been a prodigy of aural acuity he could not have heard a Lilliputian voice any more than we can hear the cries that bats seem to utter constantly as they fly; to such sounds only the ears of their small confreres are attuned.

WITH Brobdingnagians the case is no better, for their voices must have been at the lower limit of audibility—averaging perhaps three cycles per second. At such a rate the vibrations, though they might be heard, would not merge into a continuous sound, but would seem like the sad undulations of a phonograph record dragging to a stop. Now and then a Brobdingnagian soprano or piccolo player might have produced some notes that Gulliver could hear normally, but the sensation could hardly have been pleasant, for the lowest (as well as the highest) tones to which our ears are sensitive can be heard only when they are so loud that they can also be felt. Thus Gulliver was doubly wrong in claiming that he improved the giants' music by retreating from its loudness: most of it would not have sounded like music at all, and those few notes that might have had the earmarks of music would have become inaudible as soon as they became painless.

The apparently modest appetite of the Lilliputians is another reason why we may doubt their existence. Small, warm-blooded animals must take in more calories per unit of body weight than large ones, for the rate of living varies with size; small lungs breathe faster, small hearts beat faster, small bodies consume oxygen and turn out waste products faster. So a six-inch man might be expected to have about the same food requirements as a mouse,



PYGMIES of Africa are good evolutionary approximation of the smallest practical size for human being.

that is, approximately eight times as many calories per ounce of body weight as a full-scale man needs—or 24 meals a day instead of three. Gulliver missed on two counts here; he failed to realize that the creatures of his invention would have spent the larger part of their time stuffing themselves with food, and by the same token he did not see that by allowing him 1,728 times their dietary they were giving him as much food in a day as he could conveniently eat in a week.

Indeed, had Gulliver known anything of differential metabolism, his concept of a Lilliputian humanity would have been altered in every respect. For it is not difficult to see that an animal that has to provide itself with the equivalent of 24 of our meals a day would not have time enough left over for developing the nicer aspects of civilization. Worse than that, the very duration of life is related to size; an elephant may see a century pass, but fast-burning, voracious little mammals run through their lives in a space of time too brief to allow for the sort of education on which civilized society depends.

It must be concluded that the author of the Houyhnhnm hoax could have had no adequate appreciation of the physical characteristics from which human life has sprung. From the evolutionary point of view man is in essence a tall anthropoid whose big head accommodates a sizable brain and is provided with forward-looking eyes that can be used stereoscopically; he stands easily erect on flat, supple feet and carries at the end of his long, free-swinging arms a pair of instruments so beautifully designed, so perfectly adapted to uses without number, that even the products of his clever brain have never equaled them.

Our remotest apelike ancestors may not have been much more attractive than the Yahoos of Houyhnhnmland, but they were able to take the road to civilization because they were physically equipped for the journey. Their equipment did not include manual dexterity or conceptual thought, for these were goals farther along the road. Primitive man, their descendant, could enlarge the use of his brain partly because his hands, shaped by the tree-living habit of his forebears and freed by the erect posture derived from the same habit, could pick up and handle what his excellent eyes—another product of arboreal life—wished to examine; to this day the tendency to touch what we see is almost instinctive in most of us. Eyes and hands thus produced material on which the brain could work. The ideas that began to come in their turn provided work for the hands and eyes: the rock that was used as a weapon would be shaped into a blade and then mounted on a shaft; the thick-growing boughs that provided shelter would be used to construct a hut; the skins that served for clothing would be fashioned with bone needles and gut threads. Through innumerable such cycles of action and thought and action, civilization rolled slowly on toward atom bombs and prefabricated houses and the garment workers' union.

IF the indispensability of our apelike (or Yahoo-like) appointments in the development of civilization is not at once apparent, a suitable appreciation of them can be readily derived from a critical examination of Gulliver's educated horses. Even if we overlook the horse's low-browed construction, with a head so weighted down with jaws that it can hardly indulge in the luxury of a big intellectual brain, and even if we credit horse-lovers' accounts of the remarkable intelligence of the much-admired animal, we must still draw the line at Gulliver's stories of horses cooking oats, grinding flints and building houses.

An unlettered stableboy would snort at the notion of a horse threading a needle

—even if the limbs could do the trick, both eyes would be looking the wrong way! For the horse, having neither offensive weapons nor the hands to make them with, must tend first of all to his own safety; his eyes are placed to sweep a wide area for signs of danger; his limbs are designed to carry him swiftly away should danger materialize. To this end the limbs are so fixed that they swing freely in only one direction, and the body is so mounted on them that the horse, unlike certain small-clawed quadrupeds, cannot disengage his forefeet from their normal task even by sitting down. Nor is this any real disadvantage now, for the five fingers that might have led to the ability to grasp and manipulate objects were long since paid by the ancestors of the horse as the price of the stout single digit that makes such a superb running instrument. This exchange is typical of the law of compensation that nature rigidly enforces; only by refraining from specialization that might enable it to do anything perfectly has the flexible five-fingered human hand on its loose-jointed arm retained the ability to do everything after a fashion. A similar rule holds for the mind.

This brief catalogue by no means exhausts Gulliver's crimes against nature. The alterations which an increase or diminution of body size would enforce on the heart, lungs, liver and intestines could be made the subject of a large treatise. As for larks so small that they were provided with invisible feathers, eagles so big that they could not possibly pack enough power to get themselves into the air, insects far beyond the size limits imposed by the simple respiratory mechanisms of their kind—the very blades of grass in Gulliver's fantastic kingdoms cry out their impossibility. No biological principle is clearer than that every living thing—from man with his rapaciously expanding control over the environment, to the patient, insensible slime mold—lives in harmonious adjustment to the conditions of its life.

But, after all, we must not be too hard on Gulliver for failing to understand the biological conditions that made him a man—and an implausible liar. His talents, like those of his friend and teacher, the unhappy Dean Swift of Saint Patrick's, were in the psychological realm. The etymology of the name Houyhnhnm, his master horse tells us, is "the perfection of nature." Gulliver may not have understood biology, but he did understand biologists, who after his time were to endow their own species with the somewhat wishful name, *Homo sapiens*.

Florence Moog, winner of the AAAS-George Westinghouse Award for the best magazine science article of 1948, is assistant professor of zoology at Washington University in St. Louis.

WATUSI of Uganda, in East Africa, are among the world's tallest people. Many of them exceed a height of seven feet. Although there have been other kinds of big human beings, probably few were much taller than the Watusi.

EUCLID'S GEOMETRY was first translated into English in 1578. Here shown is the frontispiece of that work which, besides presenting the propositions of the Greek philosopher, promised "new Secrets Mathematicall."

BOOKS

On the nature of mathematics and of mathematicians: two new semi-popularizations of the subject for intelligent laymen

by James R. Newman

WHAT is mathematics? What use is it? What are mathematicians like? How is mathematics related to our society and culture? Here before me are two new books on mathematics which furnish at least a partial answer to such questions. They are "Makers of Mathematics," by Alfred Hooper (Random House, New York) and "Mathematics, Our Great Heritage," edited by William Schaaf (Harper & Brothers, New York). Both volumes have something useful and interesting for the adult who is not given to boasting of the fact that while he may once have been taught the method of manipulating fractions he has long since forgotten it—and good riddance.

The questions are not easy, and like all profound or philosophical questions they have produced a large literature of unsatisfying answers, ranging from the baffling to the merely silly. "The Mathematics," said Francis Bacon, makes a man "subtle." But in this the Lord Chancellor was no more accurate than usual. For one thing I doubt that mathematics makes a man anything, in the sense that glass-blowing swells the cheeks or ballet dancing strengthens the calves. It may be that subtle men become mathematicians, but this, on my experience, seems unlikely. Mathematics has its subtleties, to be sure, but they are peculiar to its domain and are not the subtleties of painting, jurisprudence, theology or finance.

A psychologist might of course describe the strong points and quirks of the mathematician, but I have yet to see it done convincingly. Mathematicians are often credited with such attributes as "spatial intuition," "analytical powers," "number-sense," "logical mind." Yet what do these loose phrases tell us? Does not everyone possess such virtues to a degree? And are we any wiser for being told that the mathematician possesses them to a higher degree than others do—as if to say that Isaac Newton was like everyone else except that he concentrated more effectively?

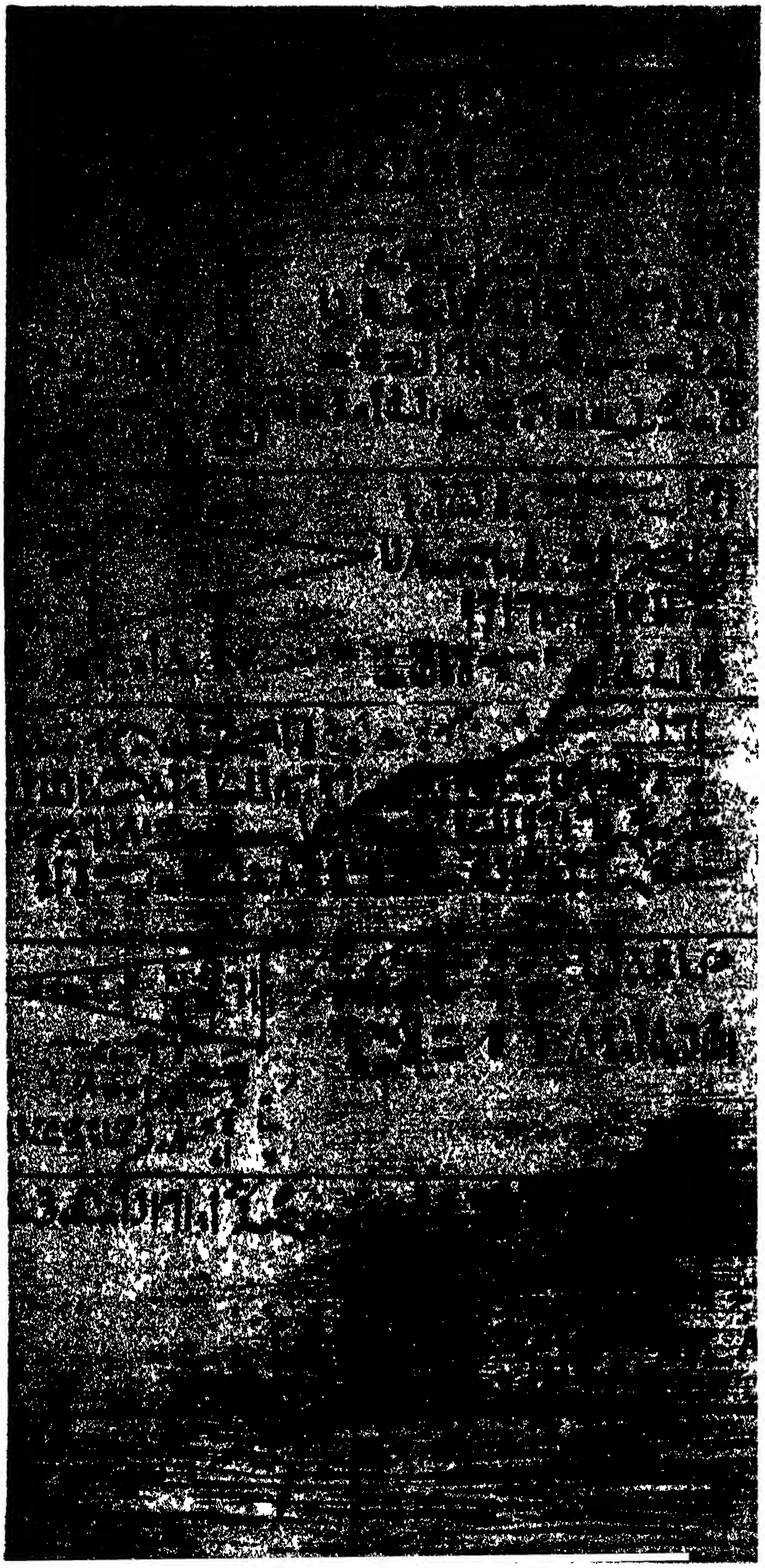
Another way of analyzing mathematicians would be to define what they feed on. To the first known mathematical treatise, the Rhind Papyrus of ancient Egypt, Ahmes the Slave gave the title *Directions for Knowing All Dark Things*—which is still appropriate after 4,000 years. But we can hardly rest there. Plato felt that men were unfit to be leaders unless they knew geometry. If the test were applied to the members of Congress, we would no doubt lose the services of a number of statesmen, but is there reason to believe that the replacements would be better? Mathematics has been defined as the "science of quantity or magnitude,' which has the one dubious merit of being obviously wrong. The Harvard mathematician Benjamin Peirce said that "mathematics is the science which draws necessary conclusions"—as one might do if a fish were found in the milk pail. Some eminent men have suggested that mathematics is no more than a branch of logic; their opponents, evidently utilizing Oscar Wilde's famous formula for manufacturing epigrams, have replied that logic is no more than a branch of mathematics. In our times we have enjoyed a number of brilliant (and occasionally impish) definitions by Bertrand Russell. On the other hand, with the German mathematician David Hilbert's flat dictum that "mathematics is a meaningless game" we have come a good distance from the somber reflections of Ahmes the Slave. It is evident that this is not the path to our goal, since the guides so strongly disagree.

The two books which are the subject of this review have at least the virtue that they are more concerned with explanation than with epigrams. Alfred Hooper's "Makers of Mathematics" is a pleasant, lucid and unpretentious survey, embracing a number of elementary branches of mathematics extending through the calculus. It combines exposition with historical material, mostly in the form of anecdotes about the great mathematicians, which have been skillfully selected so as to lubricate the more didactic portions of the text. Hooper's book does not compete with other accounts such as Alfred North Whitehead's *Introduction to Mathematics*, Lancelot Hogben's *Mathematics for the Million*, Tobias Dantzig's *Number: The Language of Science* or Eric Temple Bell's *Men of Mathematics*. Each of these is a more original contribution to the literature of mathematical popularization, and each possesses special attributes not to be found in Hooper. Hooper does not claim to be either a historian or a philosopher, and he lacks Whitehead's rare gift for striking to the heart of a difficult concept with a few simple phrases. But he does well enough. He has his own fresh way of explaining the elements of mathematics, and I am inclined to think that his thoroughness, concern for detail, effective repetition and knack for apt examples will illuminate a number of mathematical ideas which for many readers would otherwise remain veiled in obscurity.

HOOPER'S sidelights on mathematical history and the etymology of terms and symbols are particularly satisfying. Take the origins of the words "root" and "surd." The Greeks did not use the word "root," but in keeping with their geometrical thinking spoke of the "side" of a square number, as 2 is a "side" of 4, and so on. When the Arabs, who got much of their mathematics from the Greeks, began to use numbers instead of geometry as the pivot of their mathematical reasoning, they conceived of a number as "growing like a plant out of a root." So 16, for example, was thought of as growing out of the root 4. In the next stage of the history of mathematics, when European mathematicians took over the Arabic advances, the Arabic word for root was translated into the Latin *radix* (from which also come "radish" and "radical"), the source of the term in current use.

As part of the same process of word transformations, which mirrors in miniature the history of mathematical development, there is the evolution of nomenclature for the irrational numbers. From this evolution came the word "surd," which is a technical name for the square root of 2, 3, 5, etc. How the word came to this duty is part of the story of the Arab legacy of science. To designate any number which can be expressed as the ratio of two integers the Greeks had the word *logos*, which ordinarily meant "word" but in this instance stood for something like "the mind behind a word," that is to say, a number that their minds could grasp. Irrational numbers, on the other hand, were called *a-logos*. Faced with the problem of translating *a-logos*, the Arabs took the word in its primary sense—*i.e.*, "without a word" or "not expressible in a word"—and decided on the Arabic word meaning "deaf." Thus al-Khowarizmi, the famous Arabian algebraist, referred to the square root of 2, as "deaf." Again, during the Renaissance, Latin scribes engaged in the task of recapturing ancient learning through Arabian books simply turned the Arabic word "deaf" into its Latin counterpart *surdus*—whence we derive the absurd term for the irrationals.

I regret not having space to tell of Robert Recorde, who invented the sign =



RHIND PAPYRUS, a section of which is here reproduced, is one of the oldest known mathematical treatises. An Egyptian work of about 1650 B.C., found by archaeologists on the site of Thebes, it shows that ancient Egyptians had a well-developed arithmetic and could even work with fractions.

for equality "bicause noe 2 thynges can be moare equalle"; or of Pascal's toothache and the cycloid; or of "jiva" and trigonometry; or of medieval barbers who called themselves *algebristas* to describe their side line of bonesetting (one of the meanings of *al jabr* is reunion); or of Napier's special piece of artillery which, he guaranteed, would "kill 30,000 Turks without the hazard of one Christian"; or of other diverting matters. Readers will doubtless also be interested in Hooper's quotation of Whitehead's famous lines on Archimedes' murder—lines with a special meaning for our period: "The death of Archimedes at the hands of a Roman soldier is symbolical of a world change of the first magnitude. . . . No Roman lost his life because he was absorbed in the contemplation of a mathematical diagram."

In "Mathematics, Our Great Heritage," William L. Schaaf of the education department at Brooklyn College has gathered a number of interesting essays on the nature and cultural significance of mathematics. Each essay is written by a mathematician of recognized academic standing and comes under one of several headings such as: The Creative Spirit, Wellsprings, The Handmaiden, Humanistic Bearings.

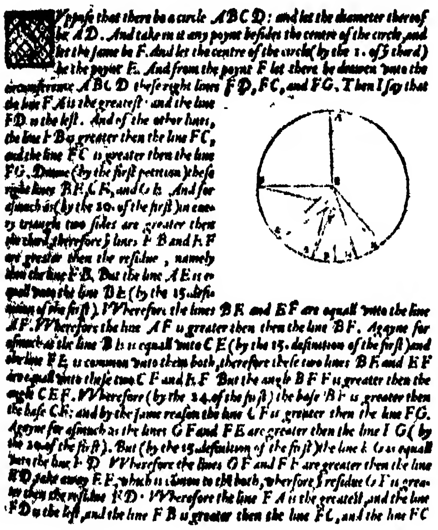
On seeing the announcement of the book I had hoped that the editor had prepared an anthology of the writings of Henri Poincaré, J. J. Sylvester, Whitehead, Russell and others of like stature But the book is a miscellany which includes the writings of none of these—only one mathematician of international reputation is represented—and it resuscitates a few essays that might well have been left undisturbed in the academic graveyard Yet the larger part of the collection is worth having in permanent form, especially because there are, to my knowledge, no other books in English covering the same ground.

For the section on the creative spirit, Schaaf has chosen J. W. N. Sullivan's *Mathematics as an Art*, one of the less impressive pieces by this sensitive and gifted writer. *Mathematics, the Subtle Fine Art*, by James Byrnie Shaw, does not say much but says it at some length in a style marked by exaltation rather than clarity. From the late G. H. Hardy's charming but not unprecious *A Mathematician's Apology* the editor has excerpted a few pages supporting Hardy's thesis that mathematics is a "serious" subject—a thesis which, in all seriousness, I had not thought required proof. Nevertheless Hardy's illustrations of "serious" mathematics are set out with economy and high skill, and there is a certain something about a master craftsman practicing his craft which gives joy to the onlooker.

E. T. Bell, an able mathematician and an intelligent, colorful commentator on the history of the subject, remarks, in a fragment taken from his *The Development of Mathematics*, that the 20th cen-

tury "led to what appears to be the final abandonment of the theory that mathematics is an image of the Eternal Truth." The same point is made by several other contributors.

John Von Neumann, another contributor, is among those mathematicians who have emphasized another aspect of this idea in insisting that mathematical foundations (which determine the mathematical system that follows) are matters of taste, and their choice is not compelled by some higher law. One may of course seek to develop systems of the greatest practical use, but this is a matter of applied rather than pure mathematics, and there is in any case no intelligence capable of foreseeing how useful the consequences of a given bundle of postulates may turn out


Suppose that there be a circle ABCD: and let the diameter thereof be AD. And take in it any poynt besides the centre of the circle, and let the same be F. And let the centre of the circle (by the 1. of the third) be the poynt E. And from the poynt F let there be drawen unto the circumference ABCD these right lines FB, FC, and FG. Then I say that the line FA is the greatest and the line FD is the least. And of the other lines, the line FB is greater then the line FC, and the line FC is greater then the line FG. Drawe (by the first petition) these right lines BE, CE, and GE. And for asmuch as (by the 20. of the first) in every triangle two sides are greater then the third, therefore the lines EB and EF are greater then the residue, namely then the line FB. But the line AE is equall unto the line BE (by the 15. definition of the first). Wherefore the lines BE and EF are equall unto the line AF. Wherefore the line AF is greater then then the line BF. Agayne for asmuch as the line BE is equall unto CE (by the 15. definition of the first) and the line FE is common unto them both, therefore these two lines BE and EF are equall unto these two CE and EF. But the angle BEF is greater then the angle CEF. Wherefore (by the 24. of the first) the base BF is greater then the base CF; and by the same reason the line CF is greater then the line FG. Agayne for asmuch as the lines GF and FE are greater then the line EG (by the 20. of the first). But (by the 15. definition of the first) the line EG is equall unto the line ED. Wherefore the lines GF and FE are greater then the line ED: take away FE, which is common to them both, wherfore the residue GF is greater then the residue FD. Wherefore the line FA is the greatest, and the line FD is the least, and the line FB is greater then the line FC, and the line FC

PROPOSITION in Euclid's geometry, as it is set down in first English translation, is good example of the mathematician's "useless" curiosity.

to be. Tobias Dantzig gives an admirable summary of the usefulness of "useless" ideas:

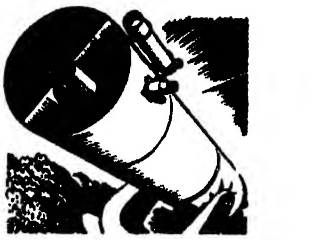
"The conic section, invented in an attempt to solve the problem of doubling the altar of an oracle, ended by becoming the orbits followed by the planets in their courses about the sun. The imaginary magnitudes invented by Cardan and Bombelli describe in some strange way the characteristic features of alternating currents. The absolute differential calculus, which originated as a fantasy of Riemann, became the mathematical vehicle for the theory of relativity. And the matrices which were a complete abstraction in the days of Cayley and Sylvester appear admirably adapted to the exotic situation exhibited by the quantum theory of the atom."

What of the sociology of mathematics? Apart from regarding mathematics as a culture clue, one may ask: How is mathematics motivated? How do its forms, the various lines of its development, the rate and direction of its growth depend upon social and economic circumstance? The inquiry is in its infancy; even Dirk Struik of the Massachusetts Institute of Technology, who for some years has investigated the relation between mathematics and the social order, has only provisional suggestions to offer.

Among the best of Schaaf's entries are the essays by C. V. Newsom and C. G. Hempel which discuss the nature of mathematical thought, its relation to logic and the problem of mathematical truth, touched on earlier by Bell and Dantzig. What is the most that can be claimed for a mathematical system? Only, it appears, that it is consistent; not that it is true. The journeys of mathematicians in search of the slippery essence of truth are like the journeys of the Princes of Serendip who, seeking one thing, often by accident or by sagacity found another. In quest of one overriding truth mathematicians have found many truths but not the one they sought. One might have hoped that the grand attempt within its own confines to prove a mathematical system consistent would have been forever ended by Kurt Godel's prodigious and terrifying demonstration that any program to prove consistency in mathematics "will lead in itself to inconsistency." But the academicians quarrel among themselves and the search for the great truth continues.

THE dissection of mathematical concepts resembles the attempt to smash the atomic nucleus and to uncover the ultimate elements of the physical world. Mathematicians, recognizing that the fundamental postulates from which their systems are drawn are true only by definition, seek to mitigate this blemish by reducing the fundamental or "primitive" concepts to a minimum. Among the vexing questions that arise is not only: What are the fewest and most primitive primitives from which fruitful results may be obtained? There is also the question: How is the choice of primitives forced by our mode of thought? And the answer to the second question must always be suspect as a product of the circular process of passing from thought to thought.

With respect to applied mathematics, Dr. Hempel states the matter very well when he says: "While mathematics in no case contributes anything to our knowledge of empirical matters, it is entirely indispensable as an instrument for the validation and even for the linguistic expression of such knowledge." In this area the criterion of mathematical validity is entirely pragmatic, but we are to remember that "it is not nature that is mathematical; man is merely reflecting the quality of his own thought processes while in the act of trying to comprehend nature." So we might conclude that the experiences we experience, the thoughts we think, the dreams we dream, all thoroughly mixed together, are the stuff of mathematics. Nor are we likely by the successive distillation of abstractions to get much closer to the heart of the problem.



THE AMATEUR

Conducted by Albert G. Ingalls

MOST small telescopes are kept pointed at the star that is being observed simply by moving their tubes along by hand as the earth's rotation carries the star across the field of view. The same result can be accomplished a little more nicely with a handscrew on the telescope mounting. If the telescope tube is too long for the observer to reach this handscrew, it may be given an extension—a long swiveled rod with a handle at one end.

An amateur telescope maker, E. S. Ensign of the Ensign Foundry Co., 2100 Hendon St., Toledo, Ohio, has devised another kind of extension "rod," an electrical one. On the mounting of his telescope—a four-inch refractor made by himself—is a tiny electric motor (145 r.p.m.). In the observer's hand is a spring switch on the end of a flexible cord. Whenever the observer presses the switch the motor sets and keeps the telescope in motion until he releases it.

Actually, there are two switches. These are soldered together as shown in Russell Porter's drawing made from the original. The over-all circuit is shown in the diagram. There are eight cells on either side of a neutral wire. Thus the motor can be reversed.

Better still, the plunger-type radio switches used combine rheostats. This permits micro control of the telescope.

It all looks fine in the illustrations, but it proved to have one "bug." Ensign writes, "I have found that no matter how tightly I set up the tripod screws the telescope shakes when the motor is started and stopped." If a prize were offered for a torsion balance the familiar structure called the tripod might win it. Vertically a tripod is as stiff as a post. Laterally it is stable in any situation short of a hurricane. Due, however, to an inherent diagonal weakness it is rotationally unstable. If a long object, say a telescope, having a large moment of inertia and a slow period of oscillation, is placed on top of it, this instability is accentuated. Add a breeze and your prize is won. Despite this, tripods have good points—at least show us something better. One of these points, however, is not their use as engine beds or motor pillows. Ensign is substituting an iron pedestal for the tripod and retaining the electrical feature.

One experimenter who reads this department recently remarked that the lot of

Porter-revised Springfield mounting cast in aluminum by Ensign

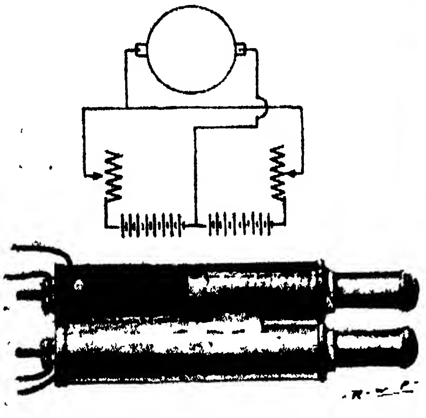
ASTRONOMER

the experimenter would be a happier one if other experimenters would similarly record not alone their successes but their mistakes. This department likes to publish valuable mistakes.

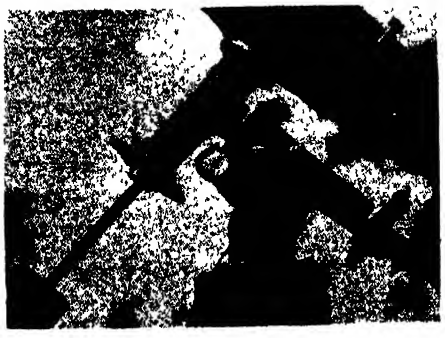
Ensign's refractor mounting was cast in aluminum. The polar axis has at top and bottom, respectively, 1¼-inch and ⅝-inch double-race ball bearings. The declination axis shaft turns in a plain bearing.

SINCE Ensign runs a foundry he was well situated to make a Springfield mounting more closely similar to Porter's revised Springfield described in *Amateur Telescope Making—Advanced* than any this department has seen. Perhaps because the patterns look formidable the revised Porter Springfield has seldom been tackled. After examining the original of the photograph reproduced here, Porter remarked, "A fine-looking job." This more than casual remark—for Porter doesn't effuse—carried more than common weight to one who has heard him loudly say nothing when shown photographs of compromise Springfield jobs.

Ensign writes: "The mounting was made from Porter's design in *ATM 4*. The main casting is aluminum with a ground steel insert to take the axis tube. The



Wiring diagram; switches



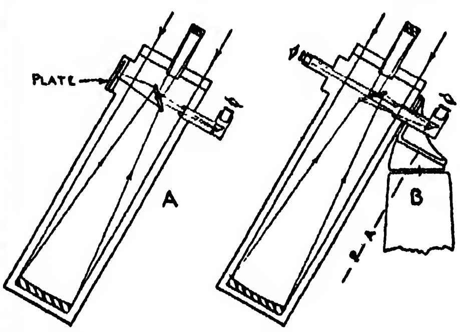
Ensign's telescope control

clutch plate is brass and has a stud staked to it which comes through the slot in the casting near the top. The stud is fitted with a handle and pinion gear running on a segment of curved rack, thereby giving a sort of vernier in declination. This was done to take the place of the more difficult worm-and-gear method, as in the original design. The worm gear for the hour circle was made on a 10-inch Logan lathe. I cut it with a ⅝-inch tap and it came out well except that the teeth don't match very well on the complete revolution. The base casting is also aluminum, but I should have used iron, as aluminum is not heavy enough. The mounting is to be used with an 8-inch mirror with 10-inch tube."

Smelling a possible chance to make this rare Porter Springfield available to amateurs, this department sounded out Ensign about castings for others. Reply: "I have the patterns but we do not pour aluminum. I would have to take it to another foundry. If some now and then would like castings out of iron I could probably accommodate them, but the prices might seem steep." Ensign specializes in a low-carbon iron with nickel and chromium called Tensloy.

In the month after the above reply was received more inquiries about Springfield castings reached this department than during the previous three years. Do you believe in telepathy?

THE FOURTH illustration shows a trick Springfield telescope ("Very ingenious."—Porter) proposed by Daniel Langpoop of Los Angeles. The diagonal



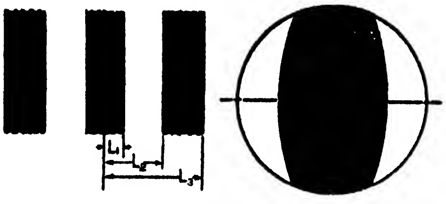
Langpoop's combination Springfield

mirror is on a pivoted support and is aluminized on both faces. In *A* the observer is guiding a photographic plate. In *B* two persons are observing simultaneously. The smaller telescope is also a finder, the best aspect of this rather stunty proposal.

ADVANCED amateur telescope mirror makers examine and study in the minutest detail the shapes and outlines of the Foucault shadows on mirrors and thus come to know their finer subtleties, many of which are not even perceived by the tyro. The same painstaking study has not yet been given the map of the bands in the useful Ronchi test. George P. Arnold of State College, Pa., and Joseph Vrabel of Boalsburg, Pa., argued heftily about the

curvature seen on the Ronchi bands in testing a short-focus mirror they were making. Should these bands neck in as much as they did at the top, or should they have the same curvature everywhere along their length?

This started Arnold, a graduate student in physics, on a hunt for a general formula by means of which the exact shape of the bands for a mirror of given specifications may be worked out in advance for



Grating distances. Compass setting

the particular Ronchi grating used. He found one which he says will do the trick with fewer pains than may at first appear. "Of interest," he comments, "is the fact that one formula can give so many shapes." On its use he has prepared what follows:

The correct appearance of the bands for any point inside or outside focus may be plotted. The lines are drawn in for the separations between the light and dark shadows thrown by each wire or edge of the grating, and the areas within these boundaries are blacked in solid. The formula is:

$$x = \frac{LR^2}{N}\left(\frac{1}{s^2 \pm r^2}\right) \quad \text{where}$$

x is the distance of a point on a band from the vertical diameter of the mirror;

L is the distance of an edge of the actual grating wire measured horizontally from the optical axis;

R is the radius of curvature of the mirror;

N is the fractional correction (for a parabola, $N=1$);

r is the distance of a chosen point on a band from the optical axis;

s is the radius of the zone at the focus of which the grating lies. (s is related to the distance of the grating from the center focus by $d = Ns^2/R$.)

The plus sign is used in the denominator if the grating is outside the center focus, and the minus sign if it is inside.

The formula is easy to apply, using cross-section paper and a compass. Take, for example, a six-inch $f/8$ mirror and a grating having 200 lines per inch. Suppose we want the correct appearance of the bands when the grating is 0.15 inch inside center focus. In this case L_1 is 0.00125 inch; L_2 is three times that amount or 0.00375 inch; L_3 is 0.00625 inch; R is 96 inches, N is 1; and, since s^2/R is to be 0.15 inch, s^2 is 14.4.

Confining our attention to one side of the first band we have

$$x = \frac{(0.00125)\ (96)^2}{14.4 - r^2}$$

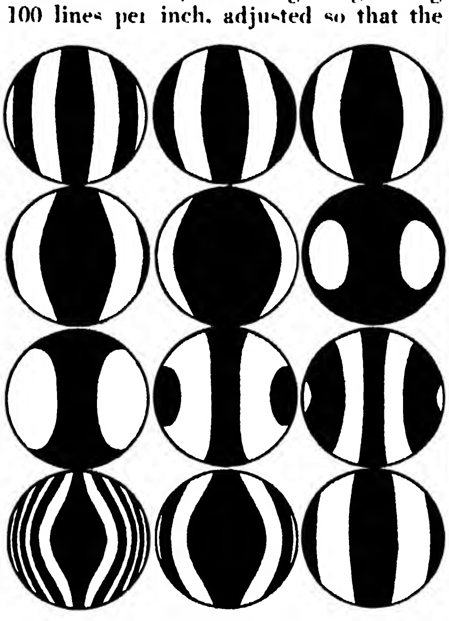
The compass is set at values of r and swung to the corresponding x's calculated from this equation, where points are marked. Enough points are plotted to enable a smooth curve to be drawn joining them. This is done for the L's on both sides of the center until the bands no longer fall within the circle which represents the mirror. Any values of x that turn out larger than the corresponding r are discarded.

One of the illustrations shows the results of applying the formula to four 6-inch mirrors; once I started this I couldn't stop—the drawings looked so pretty. They were done with some care.

Drawings 1 to 9, reading across from left to right, show the appearance of an $f/8$ paraboloid, with a grating having 200 lines per inch, located at various positions ranging from 0.15 inch inside to 0.30 inch outside the center focus, 5 being the appearance at focus.

Ten is an $f/3$, 11 an $f/5$, both having been made with the grating at the focus of the center zone. Compare with 5.

Twelve is the $f/8$ with a grating having 100 lines per inch, adjusted so that the



Four worked-out examples

band width is the same as in 2. Note the decreased curvature.

Since the formula gives only the lines separating light and dark areas, the black and white bands may be interchanged and the effect will be that obtained by moving the grating laterally half a line.

Because of diffraction the bands will never appear exactly as shown. If, however, the grating is not too fine and is kept fairly close to focus the figures will agree closely with the actual patterns, the main difference being a slight widening of the bands. Very fine grating wires give bands that may be several times the geometrical band widths.

The formula was developed independently of the method and related formula that are alluded to in *Amateur Telescope Making—Advanced*, page 108. That approach was developed in 1932 by Franklin B. Wright.

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December 1948

LETTERS

Sirs:

Yesterday afternoon I had the pleasure of leading a discussion in a group of perhaps twenty-five members of the Natural Science Faculties of Williams College based on George Gamow's "Origin of the Ice," which appeared in the October *Scientific American.* I believe that I am reporting the conclusions accurately when I say that the group felt that Gamow's account of Milankovitch's computations gave a very satisfactory explanation of glaciation during the past 600,000 years. They felt, however, that this was a very short time scale at the end of a very long history of intermittent glaciation on this planet, and questioned whether the astronomical explanation alone was sufficient to account for the very long periods of unusually warm conditions which occurred during the geological ages preceding that covered by your article. They rather felt that the article implied that "here is the cause and the whole cause" though it may not actually have said that in so many words.

Why not another article soon by some competent glaciologist presenting the whole known history of glacial ages, together with other possible explanations such as changing elevation or carbon dioxide in the atmosphere which may well have combined with the planetary perturbations to produce the ancient glacial ages and also the very long interglacial ages?

THEODORE G. MEHLIN

Department of Astronomy
Williams College
Williamstown, Mass.

Sirs:

According to George Gamow's article "Origin of the Ice," which was published in your October issue, the ellipticity of the earth's orbit is an important factor in the relative severity of the seasons, and in the occurrence of terrestrial ice ages. Dr. Gamow says, "Winters in the Northern Hemisphere, coming when the earth is closest to the sun, are at present milder than those in the Southern Hemisphere, and the summers are somewhat cooler."

The astronomer F. R. Moulton has called attention to the interesting fact that because the earth obeys the law of areas in its motion around the sun, the total amount of radiation received during corresponding seasons at points in equal northern and southern latitudes are equal. "The deficiency in the amount received per day in the Northern Hemisphere during its summer, as compared with the amount received per day in the Southern Hemisphere during its summer, is exactly counterbalanced by the greater number of days of summer in the Northern Hemisphere." This being the case, only secular perturbations, the decrease of the solar mass by radiation, and the momentum effects of the radiation itself (all of which affect the mean distance of the earth from the sun) would be significant in connection with mean temperatures on the earth. Presumably these changes are too slow to account for ice ages as recent as 25,000 years ago.

No mention was made, in the article by Dr. Gamow, of the relatively well-known fact that the solar system, in its motion through the galaxy, may often pass through regions of obscuring matter. A small screening effect would easily cause the small temperature drop necessary to produce an ice age.

WILLIAM A. CALDER

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Decatur, Ga.

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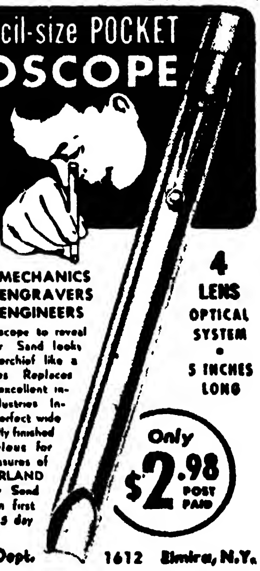

50 AND 100 YEARS AGO

DECEMBER 1898. "The population of the globe, according to M. P. D'Amfreville, is about 1,480,000,000, distributed as follows: Asia, with 825,954,000; Europe, with 357,379,000; Africa, with 163,933,000; America, with 121,713,000; Oceanica, and the Polar regions, with 7,500,400; Australia, with 3,230,000; or a grand total of 1,479,729,000 souls. It is stated that of every 1,000 inhabitants of the globe, 558 live in Asia, 242 in Europe, 111 in Africa, 82 in America, 5 in Oceanica and the Polar regions, and only 2 in Australia. Asia thus contains more than one-half of the total population of the earth, and Europe nearly one-fourth."

"The question of the relative strength of the navies of the world, with particular reference to the standing of the United States, cannot fail just now to be of vital interest. In the three brief months of the Spanish war, the supreme importance of sea power was brought home to the American people in a series of events the significance of which they have not failed to perceive. Great Britain easily maintains the position which she has set for herself, of being equal in power to the next two strongest navies, those of France and Russia; and the fact that we have moved up to fourth place with a substantial lead over Germany and Italy, will be a pleasant surprise, and highly gratifying to all those who are interested (and who is not?) in the growth of our naval power."

"Although New York City did not undertake the construction of lofty office buildings until they had become a familiar feature in the architecture of some Western cities, it has run them up in such numbers and to such unprecedented height in the last ten years that they have now become the most characteristic and obtrusive feature of its architecture. Towering high above the tallest of these great structures is the vast bulk of the Park Row building, which lifts its twin towers 29 stories and 390 feet into mid-air. Omitting the Great Pyramid of Egypt, it is conspicuously the tallest inhabited building in the world."

"Dr. Koch has recently left Rome, after six weeks of study in the hospitals where are treated cases of Roman and Campagna fevers, and in which he has been aided by the foremost specialists of Italy. As a result of these studies, it is now declared that the malarial fevers of Italy are identical in cause and general character with those of East Africa, and it is believed that science is on the eve of a decisive victory over this whole group of maladies by means of liquid injection of quinine into the pulse vein. The importance of this discovery to Italy will be evident from the fact that of the 69 departments into which that kingdom is divided, only six are absolutely free from malaria, and 1,200 square miles, including some of the most fertile districts of Italy, are, like the whole southeastern coast of Corsica and much of Sardinia, practically uninhabitable on account of malarial disease."

DECEMBER 1848. "A short time ago, the most flattering accounts were received in this city from California about the mountains of gold and the valleys flowing with silver. Some believed it was a joke, while others believed it to be a 'hue and cry' for some speculative purpose, and to the latter implication we must plead guilty. We believed that the accounts received here a short time ago about vessels being deserted by their crews and houses by their inhabitants, who had proceeded to the El Dorado valley, was all a hoax or something worse. But it seems, after all, that Madam Rumor sometimes tells true tales. The President in his Message to Congress has confirmed the extraordinary fugitive accounts heretofore received. We hope that the gold and silver that is about to flow into the treasury of our nation will not be the means of corrupting or enervating our people. Rome was mistress of the world until her citizens drank their beverages from golden bowls. We therefore wish better fortune to our potato diggers than our gold diggers, as we consider that land to be the Golden Land, which presents the greatest number of fields waving with golden harvests."

"Those of our subscribers who remember the description of Staite's Electric Light, and the first notice of this light published in America, will be pleased to know that the discoverer has secured an English patent for the same and introduced it in London. It was exhibited last month in Hanover Square Concert Room, and examined by the most eminent scientific men in that city. It possesses the remarkable property of being without heat, not combustible, and not hurtful to the eyes, and that it could be conveyed by wires like bell wires. These are indeed remarkable properties, and we are almost sceptical upon the subject.—Were it not for the authority we would be apt to disbelieve it, but there is no doubt regarding its beauty and purity. This new electric light, it seems, is not the result of combustion, for no air is admitted to the light. All that is seen is the light in a close vase, and the wire that conveys the fluid from the voltaic battery, the circuit of which can be broken and closed at pleasure. The light of one hundred wax candles, it is said, can be furnished for two cents per hour. This is rather too loose a statement we think, but it certainly is a most wonderful discovery."

"The entire President's Message was telegraphed from Baltimore to St. Louis, the task being completed on Wednesday afternoon, in just twenty-four hours from the commencement. The message was written out in full, following the copy verbatim, even to the punctuation and paragraphs, a thing not usually done in telegraphing. The number of words was 50,000. The idea of such a document appearing in print in a city nearly one thousand miles distant from Washington, twenty-four hours after delivery is almost beyond belief."

"Messrs. Howland and Aspinwall the great shipping merchants of this city have petitioned Congress for assistance to construct a Railroad across the isthmus of Panama. The petition has met with encouragement and at present all idea of Whitney's Railroad to Oregon seems to be out of the question. California and the Bay of San Francisco seem to be the climax of a railroad to the Pacific at present."

"The cause of the accident to the steamship Great Britain, according to late English papers, has been satisfactorily ascertained to have been the derangement of the compass by the iron of the vessel!"

"The Smithsonian Institute, at Washington, is progressing rapidly. The last wing is being finished interiorly with taste and beauty. The professors are making every arrangement for the consummation of their designs; and it is thought they will be ready for operation by the middle of this month.—The west wing is up and covered in, and the main building, whose heights will be the admiration of all, is advancing as fast as the skill and perseverance of the directors can impel it."

THE COVER

The painting on the cover illustrates the unorthodox technique used in the study of cancer by Pathologist Harry S. N. Greene at the Yale University Medical School (*see page 40*). Human cancer tissue, shown in microscopic section in the background, has here been transplanted to the eye of a rabbit, where it develops as a growing pink tumor. Its ability to grow in the rabbit's eye is a test of its malignancy.

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PUBLIC OPINION POLLS

Why did they fail? A leading authority assays their weaknesses and suggests some tested new techniques that would improve their accuracy

by Rensis Likert

HOWEVER wrong George Gallup, Elmo Roper and other pollsters may have been in their forecasts of the recent election, no social scientist believes that public opinion polling itself was thereby discredited as a useful tool in social research. Actually it would be as foolish to abandon this field as it would be to give up any scientific inquiry which, because of faulty methods and analysis, produced inaccurate results. Science often learns more from mistakes than from successes. In this case, the polling fiasco of 1948 had at least two healthy results: 1) it demonstrated dramatically that polling as it is now conducted is far from being an exact science (which apparently needed public demonstration), and 2) it will force more rigorous standards upon the polling business.

It would take an exhaustive investigation to find out specifically where and how the election polls went wrong—if indeed that can ever be reliably determined. The poll results themselves were only partly responsible for the erroneous predictions; errors were also made in the analysis and interpretation of the results. Thus in the Gallup Poll, when the interviews were analyzed, a considerable block of voters was ignored. This was the group, constituting some eight per cent of all the voters interviewed, who said they were undecided and would give no indication of which presidential candidate they leaned toward. Gallup stated after the election that although four out of five of this group had voted Democratic in previous elections, these voters were disregarded in his predictions on the assumption that they would not go to the polls on election day. If his assumption was incorrect, this error might explain some of the discrepancy between Gallup's prediction of a 44.5 per cent vote for Truman and the 50 per cent the President actually received.

If the polls could be so inaccurate in predicting an election, what of their activities in sampling public opinion on complex social, economic and international issues? In that field there has been skepticism for some time. The skeptics have given many reasons for their doubts: the samples are too small or are otherwise inadequate, the problems are too complex to be dealt with in a few simple questions; the investigators are biased.

How valid are these criticisms? Just how sound are the present polling techniques, and how reliable are their results? The polls have had a great influence on political leaders, on the selection of candidates, and on the actions of legislators, government administrators and businessmen. This is an appropriate occasion for an analysis of the polls.

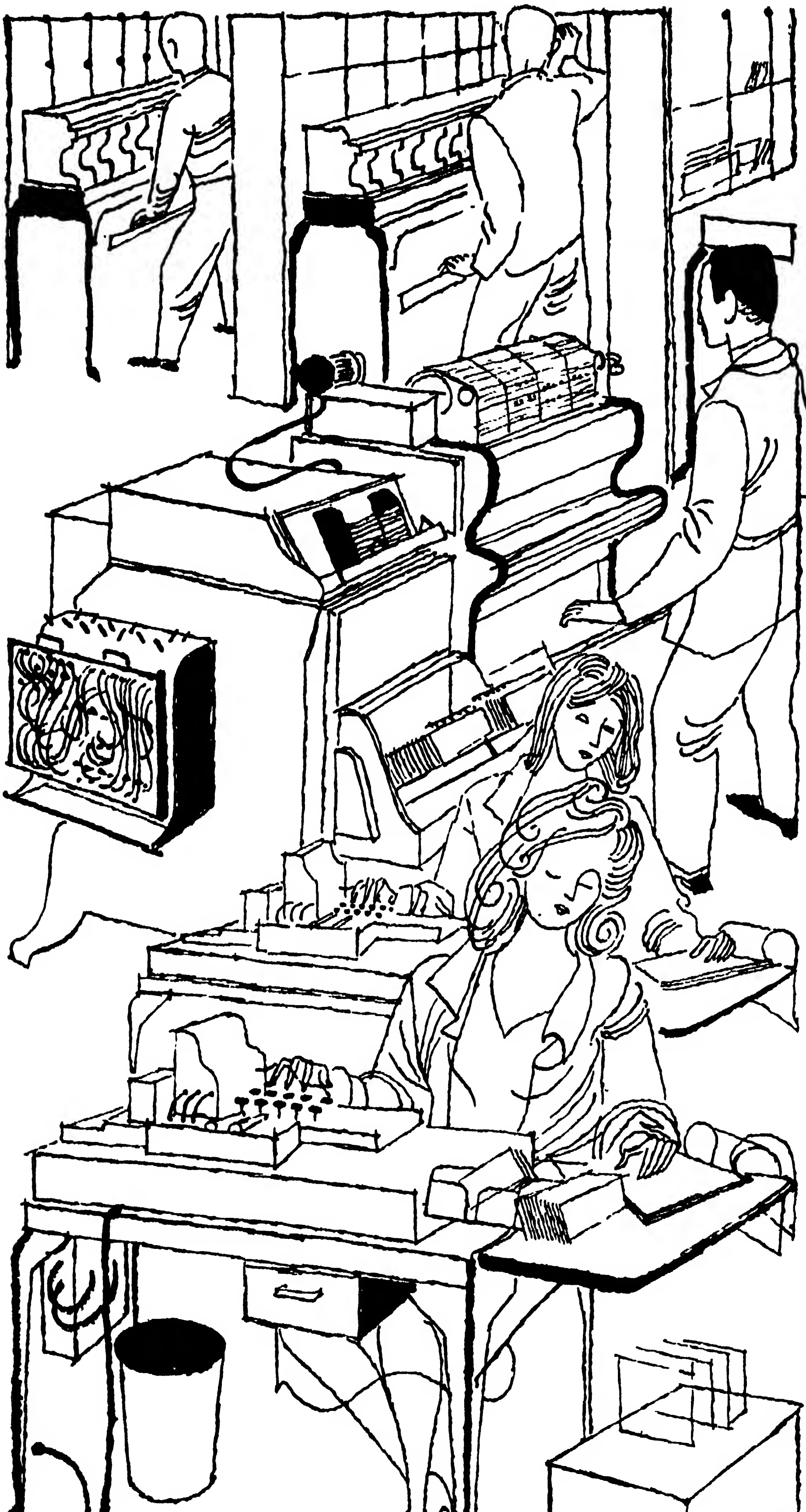
Polling Methods

The polling process divides conveniently for study into two major parts: 1) the population sample used; 2) the questionnaire, the method of interviewing and the analysis of the replies. The accuracy of any poll obviously depends upon the accuracy of each of these parts.

Let us consider first the sample. Its importance was made plain by the dramatic failure of the *Literary Digest* Poll in 1936. That poll focused attention on the fact that the design of a sample is as important as its size. With a sample of more than two million persons, the *Literary Digest* Poll still had an error of 20 percentage points. This error had two sources. First, the poll was restricted to *Literary Digest* and telephone subscribers. Second, it obtained a biased sample of those subscribers, *i.e.*, only those people who answer mailed questionnaires. The final sample therefore was not representative of the total population. So long as the voters who were not represented by the sample voted like those who were represented, the poll's predictions were borne out. But in 1936 this condition did not hold, and the poll accordingly went far astray.

The present public opinion polls use samples based on the so-called quota-controlled method. This method depends for its accuracy on finding those variables that have a high correlation with the behavior being studied. Thus to design a sample for predicting an election, the pollsters determine how voting correlates with party affiliation, age, economic status, and so on. They then attempt to find out how these variables are distributed in the whole population, and finally they assign to each interviewer quotas based on this distribution of variables: the interviewer must poll a certain number of persons in each age group, socio-economic group, etc.

For maximum accuracy, however, a pollster would need to know all of the variables correlated with voting behavior, such as previous voting behavior, education, income, occupation, religion, party affiliation of the voter's father, mother and close friends, and so forth. He would also need precise information on the distribution of all these variables in the population. Unfortunately for public opinion polling, these two conditions almost never exist. In the first place, many of the variables that affect voting or other be-



POLLING MACHINERY features the latest in business methods, such as punch tapes (*foreground*), tabulators (*center*) and mechanical sorters (*rear*), but sampling and interviewing techniques used are not so up to date.

havior are unknown. In the second place, no data are available on the distribution in the population of most of the variables that are known.

In spite of these difficulties, pollsters using the quota method have usually been able to make surprisingly accurate predictions. The methods generally employed are, briefly, as follows. Quotas are set, usually on the basis of geographical region, size of community, age, sex and socio-economic level. In some parts of the country, race also is included. In making election predictions, the results that these quota samples yield are generally tested by asking respondents how they voted in the previous presidential election and checking the percentages obtained with the actual election figures. Any discrepancy that exists is eliminated by weighting the results. For example, in a poll taken in Maine in 1944, 38 per cent of the persons interviewed said they planned to vote for Franklin D. Roosevelt. An analysis of the replies showed that the sample contained an under-representation of persons who had voted for Roosevelt in 1940. When a ratio correction was applied, a weighted estimate of 48 per cent for Roosevelt in 1944 was obtained.

This type of weighted correction has apparently sufficed to remedy the deficiencies in quota samples in most election polls in the past. There is always a possibility, however, that the high correlation between past and present voting behavior may change substantially for some important group not correctly represented in the sample, and in that case the error in the prediction may be large. It is conceivable, although there is no evidence on the point, that such a change may have occurred among some farm and labor groups in the 1948 elections.

Errors in the Samples

A major source of bias in quota samples is the fact that interviewers, in a perfectly human fashion, endeavor to fill their quotas in the easiest manner possible. They go to places where people are readily available and seek any who will fill the age, sex and socio-economic specifications of their quotas. They tend, therefore, to secure a sample which is biased in that it includes more people who are easily contacted than a truly representative sample should include. There is evidence also that some of the controls—for example, the socio-economic level—are vaguely defined.

An analysis of samples obtained with the quota-controlled method shows that this method tends to obtain data with biases which at times may be serious. For example, quota samples tend to include too few respondents from high income families. Thus analyses have shown that in typical quota samples in 1946 less than 10 per cent of the interviews were with persons in families with an income of

$5,000 or more. Census data for the same year show that actually about 15 per cent of the families had incomes of at least this amount. Quota samples also tend to have too few interviews with people of very low incomes. Another bias that often exists is the inclusion of too many persons who have at least completed high school and too few persons with grade-school education or less. Thus in typical quota samples about one third of the respondents have only a grade-school education or less, whereas census data indicate that the correct figure is about one-half.

The basic weakness of the quota-controlled method is that it does not employ a random sample. A general human failing among interviewers, or errors in the fixing of quotas, may produce a sample which is systematically biased in the same direction. In other words, when deliberate human choice enters into the final selection of respondents, the usual laws of probability governing the sampling phenomenon do not apply; the errors or deviations may not balance one another as they tend to do in a purely random sample, but at times may become cumulative and produce a bias of large and unpredictable dimensions.

A More Accurate Method

All this indicates that a method which rigorously follows random procedures will produce more accurate samples than the quota method can. Acting on this basis, a few Government and university groups have developed new methods of sampling which do indeed produce much more reliable results. These methods are called probability sampling. The fundamental requirement of probability sampling is that the final determination of just which persons are to be polled must be left to chance. Because this procedure is in conformity with statistical laws, it is possible to calculate precisely the probability that the margin of error in any sample will not exceed a given amount.

A method based on these principles is now being used by the U. S. Bureau of the Census, the Bureau of Agricultural Economics, Iowa State College Statistical Laboratory, the Survey Research Center of the University of Michigan, and other agencies. It is known as the area sample. The basic principle of this method is that each person in the population is given an equal, or known, chance to come into the sample. This is done by associating each person with one, and only one, very small geographic area and then selecting a random sample of the small geographic areas into which the country is thus divided.

The first step is to make a purely random selection of counties and metropolitan areas. Then within each of these areas a sub-sample of small geographic segments is selected, again by random methods. The final sample may include all the dwellings in each selected segment, or every kth dwelling, depending on the size of sample desired. The selection of persons actually interviewed in each dwelling will then depend on the purpose of the survey; if its purpose is to predict an election, the sample will consist of all the eligible voters in the designated dwellings or certain voters selected at random.

When this method is used, the interviewer has no choice whatever. He goes to the specified dwelling and interviews the specified person or persons. If a respondent is not at home he calls again and again until he gets the interview; if he finds it impossible to do so, he reports that fact to headquarters.

Results

Area sampling eliminates the sources of bias present in quota-controlled samples. We do not need to know the variables affecting voters or their distribution in the population. We avoid human biases in selection of the persons to be interviewed. We can compute with confidence the limits or range of error for any result obtained—which is not possible in the case of quota samples.

The greater accuracy of the area sampling method has been amply proved in practice. The Survey Research Center at Michigan, using small nation-wide samples (500 to 3,500 persons) based on this method, has obtained results which check closely with census data and other reliable criteria. For example, a series of five sampling surveys was made between June, 1946, and October, 1948. The five samples were analyzed for certain characteristics--the percentage of white persons in the sample, the proportions in various age groups, the amount of schooling, and so on. To determine whether the samples were typical for the nation as a whole, the results obtained were then compared with U. S. Census figures. Comparing the survey of October, 1948, with the most nearly comparable census data, these were some of the results:

The data on racial distribution were close to the census figures. In the Survey Research Center sample, 91 per cent of the persons interviewed were white; the census figure for white persons in the whole population is 90.6 per cent.

With regard to age distribution, 23 per cent of the sample turned out to be in the group aged 21 to 29, and the census figure for the same group is 22.8 per cent; in the other age groups the correspondence was equally or almost equally close.

In the results on schooling, the proportion who had gone no farther than grade school was 44 per cent in this survey and 46.1 per cent in the census; those who had finished high school were 23 per cent of the sample, 22.9 per cent in the census; those who had finished college, 5 per cent of the sample, 5 per cent in the census.

These results were obtained with a random sample of only 1,151 persons widely distributed around the country. The four other surveys in this series, using even smaller samples (about 600 persons each), yielded approximately the same results; for example, the range in percentage of white persons in the four samples was from 89 to 91. Similarly consistent findings have been obtained in various area-sample surveys of family incomes and other variables in the population.

Another kind of check has been made by expanding the results from a sample to an estimate for the nation as a whole. Thus in an area-sample survey made for the Federal Reserve Board in January and February, 1948, the Survey Research Center asked 3,562 households the amount of their 1947 money income; as a check, the average family income in this sample was multiplied by the number of private households in the nation, as estimated by the Census Bureau. The estimate of national income obtained in this way proved to be 10 per cent less than an estimate by the Department of Commerce based on aggregate data. As is to be expected, expansions of this kind show somewhat greater errors than direct comparison of percentages and frequency distributions.

The chief disadvantage of the area sample method is that it is more expensive. It costs more to design the sample and it costs much more for interviewers to take time to locate each designated respondent. But the increased accuracy of this method outweighs its additional cost. Because of the greater cost, most pollsters have resisted using probability samples and have adhered to the quota-sample method. Until the best available methods of sampling are used by those making election predictions and publishing polling results, it will be well to keep in mind that the sampling methods now employed can have a substantially larger error than is claimed. The formula now used by pollsters to compute the probable error in their polls is not applicable to quota samples; the formula is actually based on the assumption that the sample is truly random.

Interviewing

Now let us consider the other part of the polling process--the questions that are asked, the quality of the interviewing and the competence shown in the analysis and interpretation. Since these problems are somewhat different in a poll for predicting elections than in a poll measuring opinion and knowledge on social and economic issues, it will be well to discuss these two uses of polling separately.

In asking people how they plan to vote, there is little problem about the wording of the questions. People know the parties involved and know the major candidates. The names of the parties and the candidates have substantially the same meaning for all. There is a very real problem, however, in obtaining frank, unrestrained answers. Several different procedures have

been used to encourage respondents to answer accurately.

One of these is publicity, intended to inform people about the poll so they will be prepared to be interviewed. Gallup at times has had his interviewers wear badges. This publicity has incidentally produced a problem for the polls. People expect to be interviewed, and many become convinced, because neither they nor their friends are ever approached, that the poll results are fictitious and not based on actual interviews. Polls, however, use a sample of cities and counties, as well as a sample of people within these communities. Obviously, people who do not live in these particular sample points will never be interviewed. Moreover, only a very small proportion of the total U. S. population falls into any of the samples. No one should be surprised if he or his friends are never polled.

The pollsters also try to win the cooperation of respondents by assuring them that their answers will be treated as confidential; the answers are not identified by name, but are used only to compile statistical totals. Sometimes the polls use a secret ballot. The interviewer carries a ballot box conspicuously locked with a padlock, and the respondent deposits his "ballot" in the box. The evidence varies on the usefulness of this method. In some tests it seems to have obtained more accurate answers, in others less satisfactory ones. Generally it appears to encourage voting by some of the persons who would otherwise answer "don't know."

One of the most useful devices is the indirect approach. Instead of asking the voter bluntly whether he is going to vote and, if so, for whom, the interviewer first asks a series of questions, such as how the voter feels about each of the major issues in the campaign, which of the candidates can best handle farm problems, high prices, the housing shortage, foreign policy, and so on. People who are reluctant to say whom they expect to vote for will almost always tell how they feel about the issues, how strongly they feel, and which candidate they believe will handle each of the different problems best. The answers to all these questions can then be analyzed to predict the probable proportion of each group who will vote and how they will vote.

The prediction of elections involves a particularly knotty problem which often is neglected. This is the "turnout problem"—predicting who will vote. To predict an election it is not sufficient to know what candidates are favored; it is necessary to know what candidates are favored by those persons who will actually go to the polls. This means that the pollster must know which voters are most likely to vote and which most likely to stay home. Unfortunately, the pollsters have made few attempts to develop questions to measure the intensity of the determination to vote, and the results consequently have a large possible error.

After the recent election, Gallup is reported to have stated that his polls indicated a relatively small turnout, but that he did not mention this large factor of uncertainty because his newspaper clients would have accused him of "hedging." As a rule, the larger the turnout, the greater the Democratic vote, but this rule may not have applied in this year's elections. In any case, it appears likely that the "undecided" vote and the size and character of the turnout played a large part in the miscalculations of the pollsters. Had they obtained more data on these factors and analyzed them adequately, their predictions might have been less positive and less wrong.

The Questions

The measurement of opinion on social, economic and international issues, and of public knowledge about these issues is more difficult, as a rule, than the prediction of elections. The problems in this field of polling are still so serious that opinion-poll results should be taken with even greater caution than predictions about elections.

INTERVIEWER often biases sample by polling only people easy to reach.

Perhaps the greatest of these problems is that of meaning. Most of the issues of the day involve words and concepts that have different meanings for different people. On some issues large sections of the population may have no understanding of the major dimensions of the issue or the terms used. To understand the meaning of the percentages obtained in a poll, it is essential to know what respondents meant when they answered each question. Unfortunately, such data are not available. Yet polling results are often presented and discussed with the implicit assumption that each respondent understood the question and answered it from precisely the same point of view as that of the person conducting the poll.

An indication of the inadequacy of the usual polling questions can be obtained by asking a very small sample of respondents a question taken from any poll on a complex current problem and permitting these respondents to answer in their own words and to elaborate their answers. Several tests of polling questions have been made in this fashion. Quite consistently evidence has been obtained that questions on complex issues have different meanings for different people who are called upon to answer them.

Richard L. Crutchfield and Donald A. Gordon of Swarthmore College ran a test on the following Gallup Poll question which appeared in news releases of August 22, 1943:

"After the war, would you like to see many changes or reforms made in the United States, or would you rather have the country remain pretty much the way it was before the war?"

To test interpretations of this question, the investigators interviewed a cross-section sample of 114 New York City residents. After recording the respondent's initial reaction to the question, "the interviewer then encouraged the respondent to enlarge upon his answer in an informal conversational manner." The interviewers found that the initial response of their New York respondents gave substantially the same results as those obtained by Gallup for the country as a whole. But they also found that their respondents had seven different frames of reference in mind when answering the question. Some persons thought the question referred to "domestic changes or reforms"; others "technological changes"; others changes in the "basic political-economic structure of the U. S."; and still others thought it referred to changes in "foreign affairs of the U. S."

Respondents also had quite different meanings in mind when they answered "change" or "remain the same." For example, among those who answered in terms of "domestic changes and reforms" the word "change" for some persons meant shifts in a more liberal direction, such as "increases in social security," "higher pay levels," and "greater social equality for members of minority groups." Other persons meant a shift in the conservative direction, such as "change to a Republican administration," "less government control of business," and "more control of labor unions." Similarly, some of those who answered "remain the same" had in mind conservative aspects of our economy; others giving the same answer referred to liberal aspects, such as "maintaining high wages." It is obviously impossible to interpret percentages which

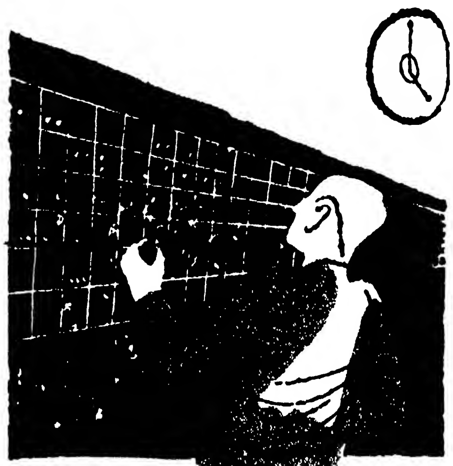
combine into single totals answers which have such widely different meanings.

This study of what the respondents really meant by their answers substantially altered the interpretation of the poll. Thus in their first answers, 49 per cent of the New York City respondents said they wanted the country to "remain the same." and 46 per cent voted for "changes or reforms." But further questioning of those who were thinking in terms of domestic changes showed that 60 per cent wanted "changes or reforms." and 40 per cent favored "remain the same"—a direct reversal of the results with respect to this phase of the question. Most of those who thought the question meant technological change favored such change, while those who thought it referred to the basic political-economic structure of the U. S. did not want change.

Many of the polls dealing with complex current issues use questions which are very likely to be as misunderstood as was the question tested by Crutchfield and Gordon. The importance of knowing what questions mean to respondents and what the latter mean by their answers is illustrated by the following two questions. which seemed similar in wording but produced substantially different results. The Gallup Poll asked: "Do you think the U. S. and all the Western European countries participating in the Marshall Plan should join together in a permanent alliance—that is, agree to come to each other's defense immediately if any one of them is attacked?" The answers: Yes. 65 per cent; No. 21 per cent: No Opinion. 14 per cent. At about the same time (the results of both polls were published in the same week—May 31 and June 2, 1948), the National Opinion Research Center asked: "As you may know, England. France and other countries of Western Europe recently signed an agreement to defend each other against attack. Do you think the U. S. should promise to back up these countries with our armed forces if they are attacked by some other country?" The answers: Yes, 51 per cent; No, 39 per cent; No Opinion. 10 per cent. Thus on what was essentially the same question—the formation of a military alliance—there was a difference of 14 percentage points in the Yes answers and 18 points in the No answers. Unless data are obtained showing what respondents in a poll actually mean by their replies, the percentages obtained are of limited significance and sometimes may be seriously misleading.

The problem becomes even more difficult when attempts are made to take polls on complex issues in several different countries at the same time. The language and cultural differences. added to all the other difficulties, are likely to make the results seriously inaccurate. In an international poll it is virtually impossible to have a complex question mean the same thing to all respondents.

There is no simple solution to this problem of the meaning of questions. One essential step is to analyze the problem in terms of psychological theories. This step works best when combined with a method of intensive interviewing using fixed questions and free answers. In using this technique. the polls would ask the respondent to select one of a number of alternative answers to a question. or would ask open questions. such as. "How do you feel about such and such a situation?" Interviewers would be trained to record the respondents' answers fully. and in the case of a question with alternative answers would encourage the respondent to elaborate his choice. using follow-up questions such as. "What do you have in mind?" The open-question method and the fixed question-free answer technique have demonstrated their usefulness in many tests. The major disadvantage of these methods. as with area sampling, is that they are somewhat more expensive than the more conventional polling techniques. Here again. this disadvantage is outweighed by greater accuracy.



STRATEGY BOARD in pollster's headquarters shows areas polled.

The Future of the Polls

Public opinion polling is a very young technique. None of the present polls was in existence 15 years ago. In less than 15 years the public opinion poll has become thoroughly established in this country, and it is gaining status rapidly in most of the rest of the world. The leaders of the polling business, particularly Gallup and Roper, are chiefly responsible for this achievement. The polls have been widely used by the public, by business and by government, and they affect many important decisions. Year by year their importance and use have increased. In spite of such failures as that in the recent election, their use is likely to continue to increase, because polls employing sound methods can obtain essential information which is obtainable otherwise only at a prohibitive cost—as by a referendum—or not obtainable at all.

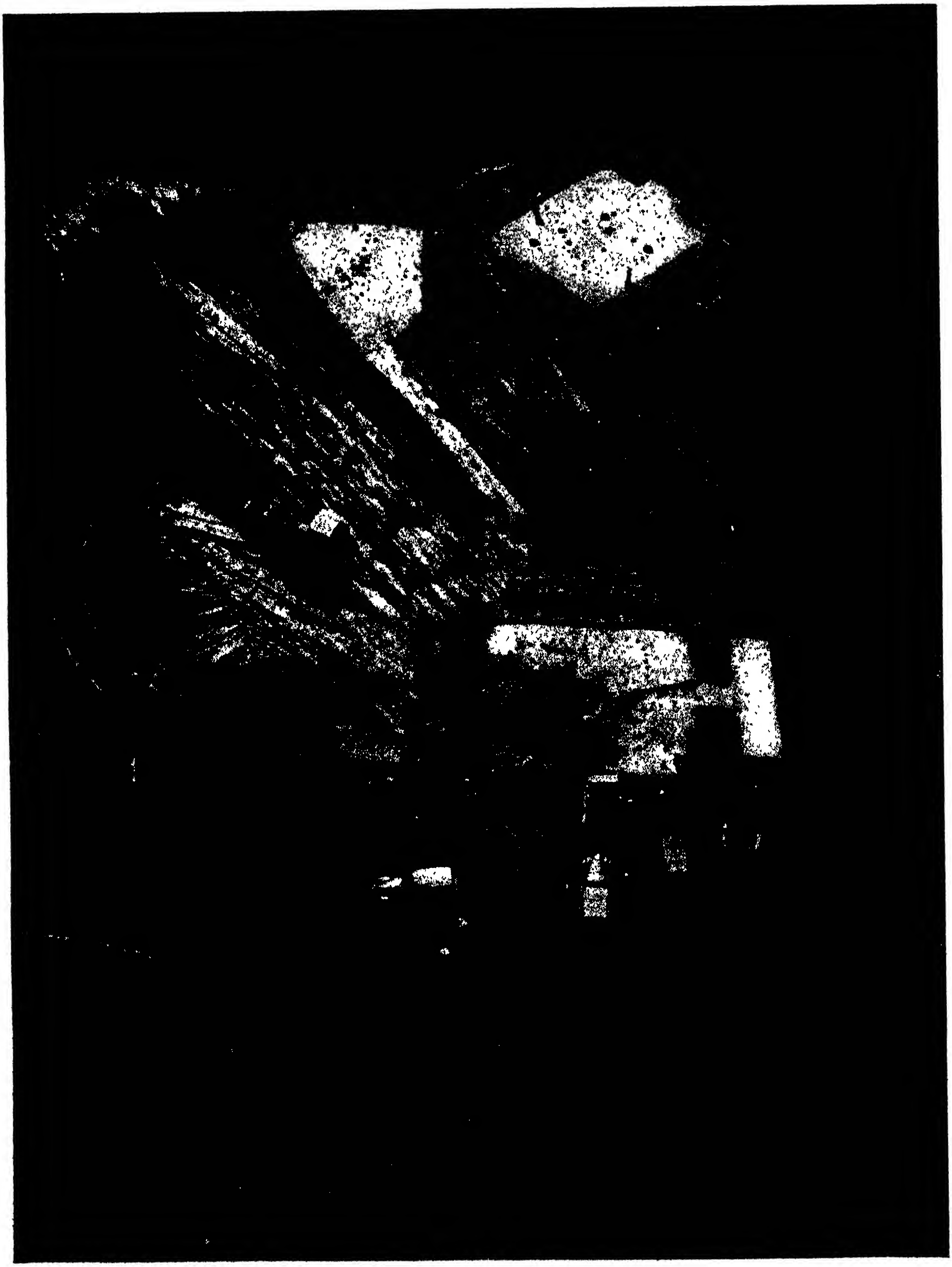
The public opinion polls therefore have a tremendous responsibility. Their readers. including all those persons who make important policy and administrative decisions on the basis of their results, rely on the polls for accurate information. The polls must use methods which will assure that their results are reasonably accurate on all issues and at all times. In terms of their own self-interest. the polls must assume this responsibility. Indeed, their ability to regain public confidence may now depend on their willingness to restudy and improve their methods.

Among the methods now available which would permit them to measure opinion more accurately are probability sampling, the fixed question-free answer method of interviewing. open questions. questions employing an indirect approach. and the use of a series of interrelated questions covering the same phase of a particular issue from several different approaches. By using the best methods available, the polls will discharge more adequately their responsibility to the public. government officials and businessmen.

The public opinion poll is only one area of application of a far more important instrument: the sample interview survey. The sample interview survey is one of the research tools of the social sciences. It is being used increasingly to study such widely different problems as the behavior of consumers, the distribution of income. principles of organization and management. religious behavior. the factors affecting political behavior. the production plans of farmers. and the processes of propaganda. Either alone or in combination with experimental methods. this tool enables the social sciences to deal with their problems in a quantitative manner. Consequently. social scientists have taken a keen interest in this technique.

A great deal of research on improvements in the technique is now going on. Some of this research is being done by the public opinion polling agencies. More. however. is being done by the Federal government and educational and research organizations. Important methodological advances are flowing and will continue to flow from this research on all phases of polling. such as sampling. interviewing and research design. Social science is making available to the polls improved methods. It is to be hoped that the polls will accept and utilize them.

Rensis Likert is the director of the Survey Research Center at the University of Michigan.



EARTH-MOVING MACHINE working on a slope at the Medicine Creek Reservoir in Nebraska is an indication of the archaeologists' haste. Here they have uncovered the sites of three dome-shaped houses built by Indians some 500 to 600 years ago. The original post holes made by the inhabitants have been dug out again by hand.

A CRISIS IN U.S. ARCHAEOLOGY

The damming of rivers will shortly flood the valleys where lived the aboriginal Americans. Archaeologists must work fast to save what they can of the remains

by Frank H. H. Roberts

DURING the past two years archaeologists have been scraping away at the river basins of the U. S. with an anxious haste that suggests Noah's preparations for the Flood. Their search parties have prospected thousands of miles of the North American watershed, searching for traces of its prehistoric inhabitants, and have staked out hundreds of sites for excavation. They are so pressed for time that in some places they are digging with bulldozers instead of with the customary archaeologist's spade. The objective of this activity—perhaps the most massive and most unleisurely excavation project in archaeological history—is to unearth as much as can be saved of North America's prehistoric remains before it is too late. For the archaeologists are actually working against the deadline of a series of impending floods that soon will bury the civilizations of the aboriginal Americans beyond recovery.

The reason for this state of affairs is the Federal government's nation-wide river development program. Its numerous projects for flood control, irrigation, hydroelectric power and navigation will inundate most of the archaeological sites in the U. S., many of which, unfortunately, are still completely unexplored. The American aborigines, like the inhabitants of other lands, generally lived along river banks, where there were fields for raising crops and good locations for camps and villages, where game, fowl and fish abounded and where easy transportation by water was at hand. For this reason, about 80 per cent of the archaeological remains in this country are located in places where the damming of rivers and the formation of reservoirs will obliterate them for all time.

The archaeologists of the U. S. have thus been suddenly presented with a problem of appalling dimensions. The construction of dams is going ahead so rapidly that they have only a few short years to carry out explorations which would ordinarily take several generations.

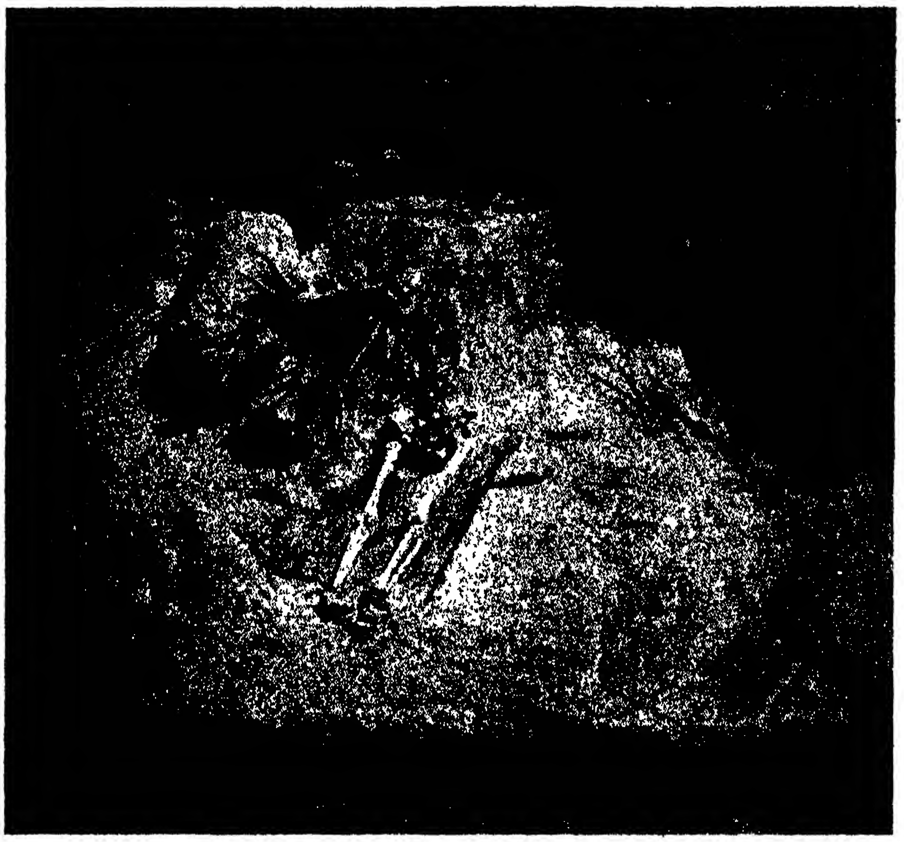
Early in 1945 they began to organize their forces. Within a year there was mobilized a large cooperative enterprise supported by the Army Corps of Engineers, the Bureau of Reclamation, the National Park Service (which is charged by law with responsibility for the preservation of archaeological sites) and the Smithsonian Institution. The National Research Council's Committee on Basic Needs in American Archaeology, the Society for American Archaeology, the American Anthropological Association and the American Council of Learned Societies formed an independent Committee for the Recovery of Archaeological Remains (including also paleontological remains) to serve in an advisory capacity and to assist in planning a nation-wide survey and digging program for all the river basins where dam projects were in prospect. As the program progressed the committee helped to enlist scientists from many universities, museums and state societies in the cooperative effort. The Smithsonian was given chief responsibility for the scientific work, and the National Park Service agreed to keep it informed of all dam and reservoir projects and to make arrangements for surveys of the areas involved.

PROJECTILE POINT is brushed by archaeologist working in Angostura Reservoir area of South Dakota.

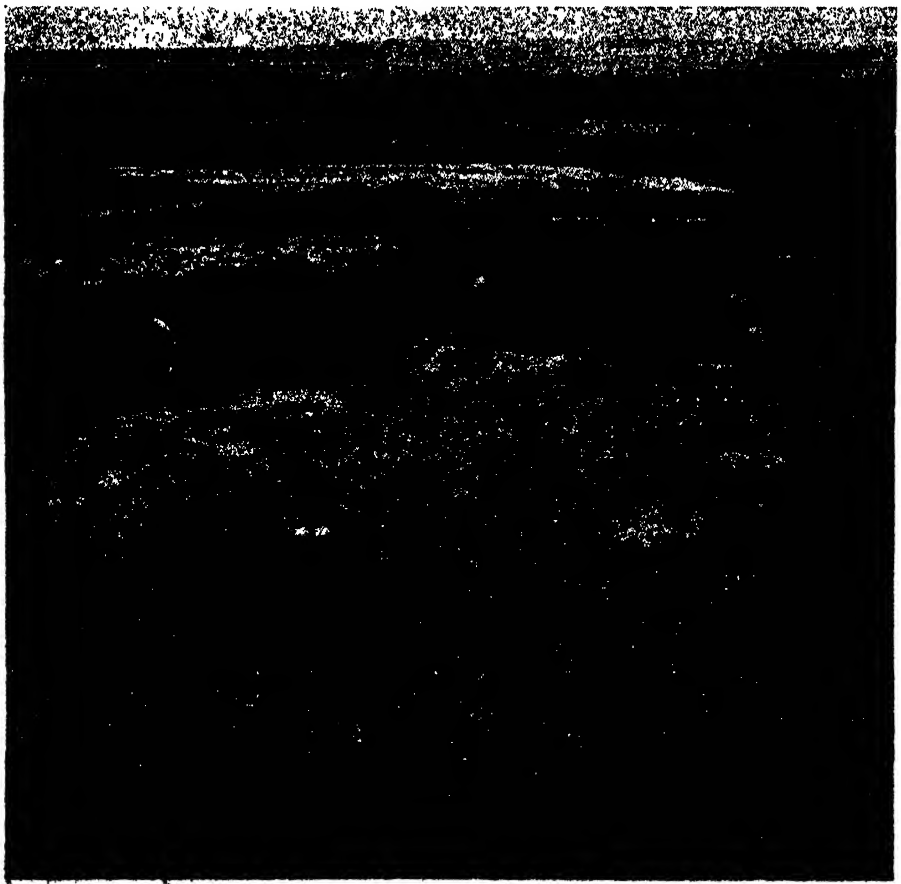
The archaeologists went to work first in the Missouri River Basin, where 105 river development projects had already been authorized. From field headquarters at the University of Nebraska, survey parties reconnoitered more than 13,000 miles of the basin and covered 94 reservoir areas. Meanwhile other parties began explorations in the Columbia-Snake Basin in Oregon, on the Etowah River in Georgia, the Roanoke in Virginia, the Brazos and Neches rivers in Texas, and in the Central Valley of California and the Arkansas drainage basin in Oklahoma. And other surveys, sponsored by individual universities, have been started or planned in a score of states from Florida to Oregon.

Thus far the central survey staff alone has located some 1,800 archaeological sites and recommended digging operations at 250 of them. Because of limited funds, large-scale digging has actually been undertaken at only nine sites: the Addicks Reservoir in Texas, Medicine Creek Reservoir in Nebraska, Angostura Reservoir in South Dakota, Heart Butte Reservoir in North Dakota, Boysen Reservoir in Wyoming, McNary Reservoir in Oregon, O'Sullivan Reservoir in Washington, Fort Gibson Reservoir in Oklahoma and the Tucumcari project in New Mexico. The cooperating universities, however, have undertaken a number of other excavations, and at many additional sites there has been preliminary test digging.

Some of these excavations are being made, with great haste, in places where the destruction of the sites by the engineers is imminent or, indeed, already under way. An example is the Medicine Creek project on the Republican River in Nebraska. There, for the first time in archaeological history, power machinery has been used on a large scale. Time and man power were so short that the archaeologists decided to risk utilizing heavy equipment, provided by the Bureau of Reclamation, to scrape away the earth covering buried villages. The experiment



SKELETON of a 70-year-old man is carefully uncovered in the same Medicine Creek Reservoir area that is shown on page 12. This region has been the most thoroughly worked of all those that will be inundated.



FLOORS of Indian houses are exposed in the Medicine Creek Reservoir area. Posts placed in the holes supported an earth-covered structure. The entrance was at rear center. The larger holes were employed for storage.

surpassed expectations; it was found entirely feasible to remove the overburden from large areas with practically no damage to the underlying remains. In five months this group accomplished as much work as would normally have taken a much larger crew two full seasons. It was therefore decided to use machinery at other sites.

The diggings have already yielded important and interesting information about the little-known prehistoric peoples of North America. Among the most significant finds have been those in the Columbia River Basin of the Northwest. There the diggers have unearthed at successive levels the buried remains of villages ranging in time from 4,000 years ago to the time of the Lewis and Clark expedition in the early 1800s. The two seasons of preliminary exploration in this relatively unknown area have turned up many camp and village sites, rock shelters and burial grounds. From the great wealth of buried material archaeologists hope to reconstruct a continuous history of the aboriginal occupation covering several thousand years. The Columbia Basin was the most important prehistoric travel route in the West; there is evidence of aboriginal trading up and down the river from the West Coast to the upper Missouri Basin.

In the Missouri Basin there have been finds of cultures much older than those on the coast. Indeed, some of the deep strata which have been exposed by streams cutting through the terrain promise to yield material belonging to the so-called Paleo-Indian, who is believed to have migrated from Asia to North America in the late Pleistocene period. Most of the sites in the Wyoming-Montana area contain no pottery—an evidence of very primitive culture. Farther east, in the western Dakotas, pottery begins to appear. In both areas great numbers of stone circles or tipi rings, marking tent sites, have been unearthed. But to the south, in northwestern Nebraska and northern Kansas, the predominant dwellings were pit houses, and in the eastern Dakotas there are many mounds and remains of villages—all suggesting a more sedentary, agricultural type of civilization.

SOME of the largest, best preserved and most impressive fortified Indian sites in the U. S. have been found along the main stream of the Missouri in the Dakotas. In some of the sites there are records of prehistoric floods, of silting and soil erosion, of recurrent droughts and of fluctuations in climate. The excavation and interpretation of the data contained in such sites should not only contribute to the story of the growth and development of the Plains Indians but also add considerably to our understanding of how the aboriginal people met and overcame climatic and other environmental conditions not unlike those of the present day. Part of this study has already been made at the Medicine

Creek Reservoir in Nebraska and at the Angostura Reservoir in western South Dakota.

The Medicine Creek area, thanks to the help of earth-moving machinery, to date is the most thoroughly explored of all the projects. Its remains consist mostly of house pits, middens (dumps for debris and refuse), cache pits where crops were stored, and burial grounds. The material already uncovered indicates that archaeologists will have to revise some of their long-held theories about the Indians of that area and their relationship to their environment. The finds show that these Indians practiced community planning and varied their housing architecture. They also shed new light on early developments in horticulture.

The Medicine Creek villages which have been excavated probably were occupied about 500 to 600 years ago. They certainly were never visited by white explorers, and so far it has not been possible to connect them with the Indian tribes that have lived in the area in more recent times. Each village consisted of a half dozen or more earth-covered, dome-shaped houses. The floors were slightly below ground level. Near the center of the large chamber in each house was the fireplace, with the smoke passing out through a hole in the roof. The entrance to the house was a tunnel-like passage, placed on the side away from the prevailing winter winds.

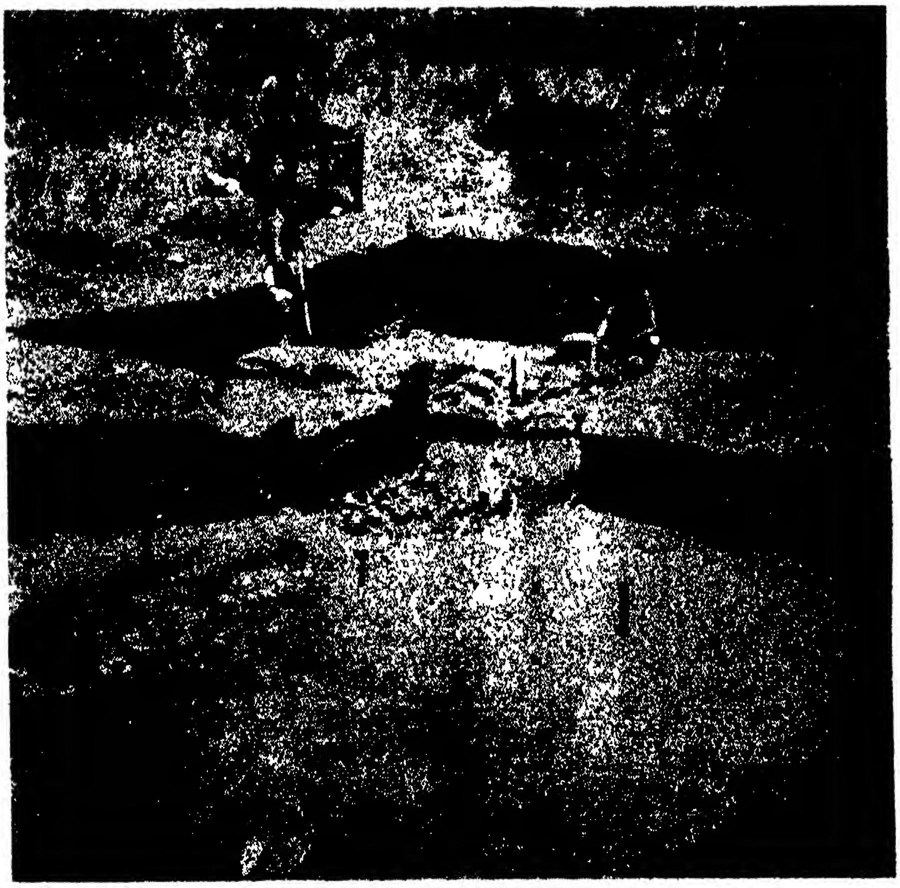
Each house probably was occupied by two or more families. Small underground pits inside and outside the houses were used for storage, and later as dumps for refuse. The remains show that these people raised corn, squash and beans, gathered wild fruits, berries and tubers, and hunted bison, deer, antelope and small game. They also depended a good deal on aquatic food; bone fishhooks have been found, and vast numbers of fresh-water mussel shells.

Just above these archaeological deposits is a thick layer of dust—evidence that the area suffered a period of severe droughts comparable to those which occurred in the Plains area a decade ago. During the drought period the Indians withdrew from the region. Later the weather improved and layers of good soil, now covered with sod, were deposited over the dust. This is just one of many proofs that cycles of good and bad times have been not uncommon in the area.

The fact that when white men first came to North America from Europe they found a virgin wilderness, apparently very sparsely populated, has fostered a wide impression that the continent had only a scanty human history. The current digging is amply demonstrating how wrong that impression is. It shows, as archaeologists have long suspected, that what is now the U. S. was peopled in ancient times by many diverse tribes occupying almost every region on the continent.

In California the present survey has un-

PIT DWELLING is dug out at the O'Sullivan Reservoir in Washington. This region was one of the most important prehistoric travel routes in U. S. Remains of villages dating from 4,000 years ago have been unearthed.



INTERIOR of pit house in the picture at the top of the page shows structural plan. Many such houses had a fireplace in the center, with a hole in the roof for a chimney. Man in rear sifts earth for small objects.

TIPI RINGS, circles of stones set on the ground to anchor Indian tipis, are plainly visible in the Tiber Reservoir area of Montana. These rings locate the sites of some comparatively recent settlements of the Indians.

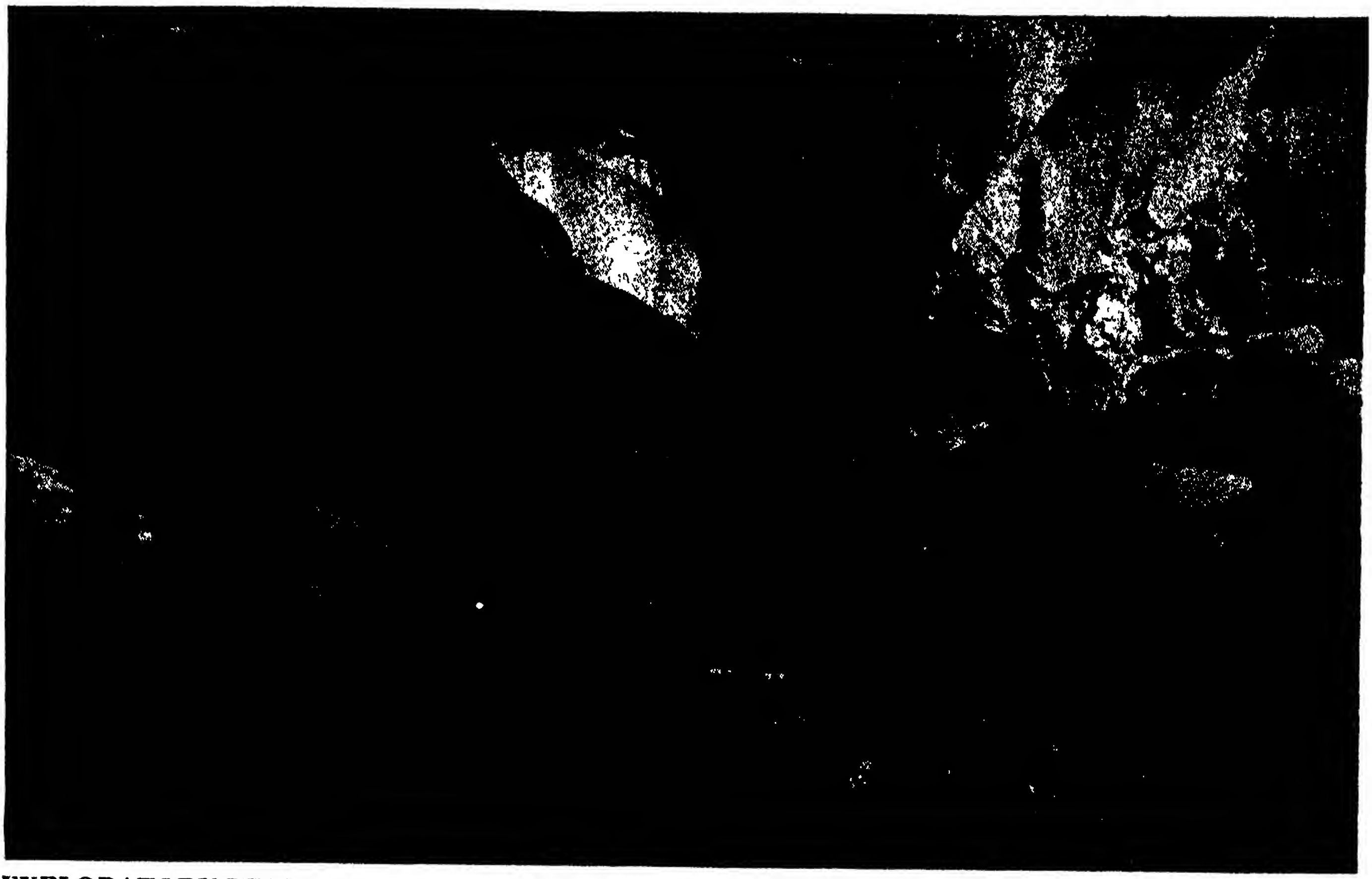
FORTIFIED VILLAGE built by the Indians is still a rough outline beside the muddy main stream of the Missouri River. This site, visible at bottom center of this aerial view, will be inundated by the Oahe Reservoir.

earthed village sites, soapstone quarries, pictographic writing and pottery of peoples previously unknown. In Texas, camp and village sites have been found in many new areas. In Virginia and North Carolina there are a number of signs of what seems to be an eastern phase of the famous Folsom culture which flourished in the Western Plains during the closing days of the last Ice Age. At the Fort Gibson Reservoir site in Oklahoma there are valuable remains which are attributed to the great mound-building era, the period of cultural efflorescence which swept across the southern U. S. in the late pre-Columbian and early historic period.

THE flooding of river basins will of course bury many deposits of fossils as well as those of aboriginal cultures. Thus far reconnaissance in this field has been confined mostly to the Missouri Basin, but it is now being extended to other areas. On the whole the loss to paleontology will not be so serious as that facing archaeology, for fossils similar to those that will be inundated can in most cases be found in other locations. A few unique quarries will be flooded, however, and there are many valuable fossil remains in the Indian sites themselves. Archaeologists frequently find fossil bones and leaves which the Indians apparently collected as curiosities. They used them as ornaments and sometimes carved implements from them.

The nation-wide effort to salvage archaeological and paleontological materials, the largest coordinated project of the kind ever undertaken in this country, has made a good start, but a staggering amount of work remains to be done, and time is running out. The great problem is lack of funds. So far the work has been financed mainly by funds transferred from appropriations of the Department of the Interior and the Army Corps of Engineers. The money available has been so limited that in many critical areas where sites are about to be destroyed the necessary surveys and excavations cannot even be attempted. As the Federal river development program proceeds, the emergency will become more and more acute. The Committee for the Recovery of Archaeological Remains is making a yeoman attempt to obtain the increased financial backing that is greatly needed. Unless more active support is provided, much of the archaeological story of North America will be lost. It will take a great combined effort by Federal, state and local institutions to achieve even a fair sampling of the nation's archaeological resources and to save a minimum of its prehistoric record.

Frank H. H. Roberts is Associate Director of the Smithsonian Institution's Bureau of American Ethnology and Director of the River Basin Surveys.



EXPLORATORY TRENCHES are dug in the lee of a cliff in the Oregon Basin Reservoir area. Indian villages were very likely established here for shelter. Layers of earth in village sites indicate that Indians lived under climatic conditions much the same as those of today. One layer indicates a long period of severe drought.

CAVE IS WORKED by a group of archaeologists in the Boysen Reservoir region of Wyoming. Deposits on the floor of the cave are carefully removed in layers. Each layer is separately sifted for artifacts. This process insures the segregation of characteristic artifacts left by the inhabitants of different periods and cultures.

The Navigation of Birds

How do they find their way in their vast migrations over land and water? Some new evidence on an old mystery

by Donald R. Griffin

FEW natural phenomena have so enchanted and puzzled men in all ages as the migrations of birds. The oracles of Homeric Greece and the augurs of the Roman Empire wove the seasonal appearance and disappearance of wild birds into their everyday religion and mythology. After the Romans, for many centuries birds received less sophisticated attention. Nevertheless their annual comings and goings have always intrigued all sorts of men from dilettantes to professional specialists. Perhaps there is a common denominator in the interest displayed by the augurs of ancient Rome and by the Audubon societies of today. No naturalistic conception of the universe seems really complete unless it deals with bird migration, and even in the most mechanistic modern climates of opinion this has been a phenomenon demanding special explanation. The attempted explanation may be a mechanistic one, but even so it is likely to be less mechanical than explanations of other phenomena. This is as true in these days of relativity, radar and mesons as it was in the time of James Clerk Maxwell and Charles Darwin. Bird migration is still something of a mystery even to those who deny the existence of mysteries.

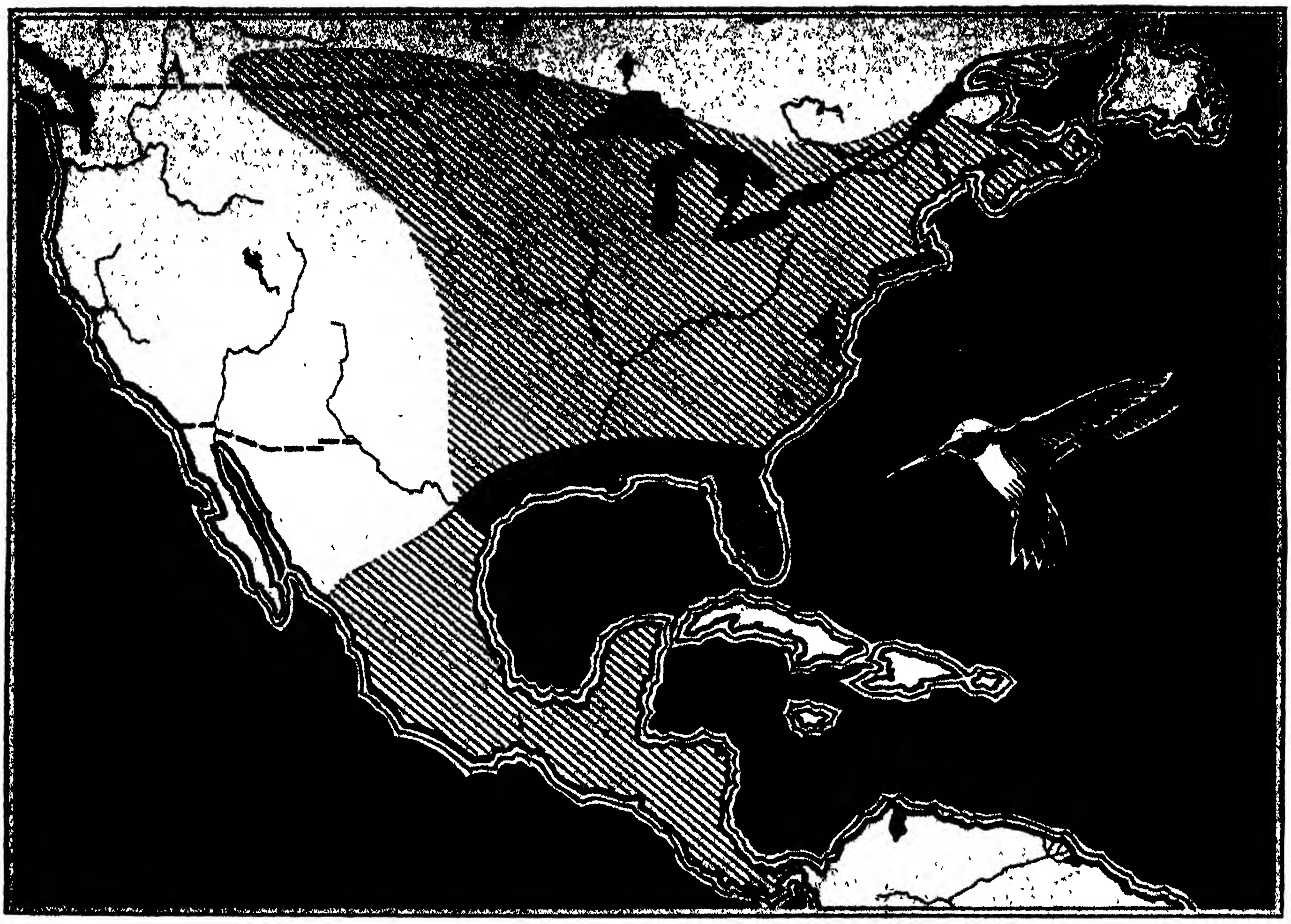
I must disclaim at once any attempt in this article to offer a solution of the mystery, but it does seem worth while to describe the progress that has recently been made toward an understanding of bird migration. During the past century the patient work of ornithologists has furnished a rather adequate description, if not an explanation, of the main features of bird migrations: their extent, the times of departure and arrival, the approximate routes followed by most species, the speed with which a whole population moves from winter to summer range, or *vice versa*. Repeated observations have established certain interesting facts, such as that some species migrate by night while others travel in the daytime; that in some species the young and old birds travel together, while in others they may migrate by entirely different routes or at different dates. The success of this description intensifies the urge to understand how the long journeys are accomplished. Of all the questions that have been asked about bird migrations, the most baffling and the most critical is the matter of orientation—how do the birds find their way?

To appreciate the dimensions of this problem one must consider the vast distances that birds often travel in their seasonal flights. While some birds are nonmigratory or travel only a few miles, as from a mountain-top to a neighboring valley, others span a major portion of the globe. One typical example is the tiny ruby-throated hummingbird (*Archilochus colubris*). This species, a familiar one in the eastern U. S., has wide summer and winter ranges, which are shown in the map on page 20. While the summer and winter ranges overlap somewhat, as they do with many birds, it is clear that individuals nesting along the Canadian boundary during the summer must migrate many hundreds of miles to reach even the northern edge of the winter range. The hummingbirds' summer and winter ranges are similar to those of many common songbirds, so that migrations of this length are the rule rather than the exception. A more extreme and spectacular case is that of the golden plover (*Pluvialis dominica*), a shore bird or wader slightly larger than a robin. Two closely related subspecies of this bird nest in the arctic latitudes of North America and Siberia and migrate to the Southern Hemisphere in winter. In addition to its great length, this migration route presents other features of interest. First, the adults seem to leave the breeding grounds before the young, so that many of the latter must make the entire journey without guidance from other golden plovers that have previously flown the course. Also, the golden plover does not swim on the water's surface, or at least has very seldom been observed to do so; it appears highly probable that the bird's extensive overwater flights, such as those to the Pacific islands or that from Nova Scotia to the Lesser Antilles, are made without stops for food or rest.

These migration routes are merely examples; many more are known to be just as extensive and to involve equally difficult feats of navigation. There are oceanic birds such as albatrosses, boobies, petrels, shearwaters and fulmars, which spend most of their lives at sea but must fly hundreds of miles to islands to lay their eggs and raise their young. The kingfisher or halcyon was believed in Aristotle's time to lay its eggs in a floating nest and to require a calm sea and fine weather for the safety of the eggs—hence the expression "halcyon days." Modern ornithology has found no birds which build nests floating on the open sea, but it has observed very remarkable habits among such birds as the petrels and shearwaters. Although highly adapted to a life at sea, these birds protect their nests from predators by digging burrows to shelter the eggs and young. Some species come ashore to enter these burrows only under cover of darkness. It is difficult even to guess how they find the islands on foggy nights. Petrels nesting on islands in the Bay of Fundy seem to prefer foggy nights, when they are safer from gulls, for their visits to the burrows, but tremendous problems of navigation must be posed by this searching for the nests.

ALL of these migrating birds must guide their flight by means of some aspect of their environment which is related in a reasonably reliable fashion to the direction of the goal. We must also take as certain, unless we are to fall back on extra-scientific theories, that this environmental cue must be perceived by the birds; it must stimulate some sense organ or receptor cells, for these are the only functional contacts between a bird's nerv-

MIGRATING BIRDS, here illustrated by a flight of swallows, often span a major portion of the globe in their journeys from summer to winter ranges. Their sense of direction has been variously ascribed to effects of the earth's magnetic field or its rotation, but these theories seem to be disproved by experimental evidence.



HUMMINGBIRD, the smallest of all the feathered species, flies huge distances in its seasonal migrations. Its summer and winter ranges are here shown by shaded areas. The summer range covers the central and eastern U. S. to the Canadian border; the winter range, which is mostly in Central America, overlaps the summer.

ous system and its outside environment. Our problem, then, is to find the environmental cue, and also to find the sensory mechanism by which this environmental cue is recognized and channeled into the central nervous system, where it can result in the appropriate actions to move the bird in the right direction.

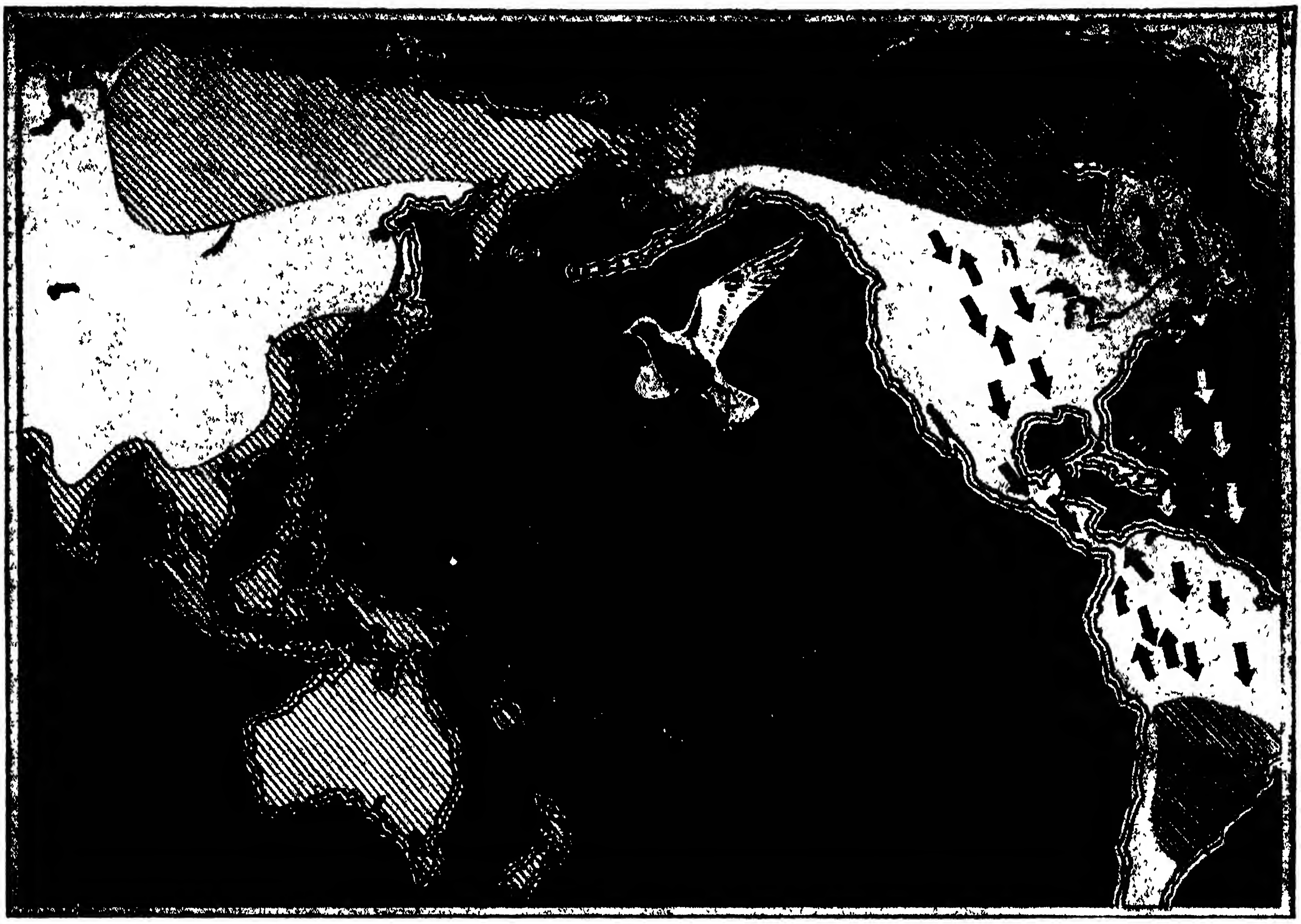
No one has yet succeeded in solving this problem, and all attempts to do so have been impaled on one or both horns of a dilemma: either the proposed environmental cue has seemed altogether too unreliable, or it has been impossible to demonstrate that the birds could perceive it.

On the first horn of this dilemma we find those who try to account for bird navigation in terms of the known sensory mechanisms, which are much the same in all higher vertebrates. Some have suggested that migrants are guided by visual landmarks. But the overwater routes such as those of the golden plover are devoid of topography for hundreds of miles, although some guidance might be obtained from the ocean swells, which tend to be rather constant in direction over any one part of the ocean. Others feel that wind direction may offer a guiding cue, but winds are notoriously changeable, and only if the bird knew the wind direction characteristic of each type of air mass and weather condition along its route could it guide itself from arctic to tropics.

The sun or other celestial points of reference might be guides, but a bird navigating by them would be obliged from hour to hour to change the angle between its flight path and the azimuth of the heavenly body upon which its attention might be fixed. Additional but smaller shifts would be made necessary by changes in longitude and latitude as the migration progressed. An even more obvious objection is that the birds migrate during overcast weather and even on cloudy nights. Answers are possible to these objections, such as the fact that even on heavily overcast days the sun's position is to some extent revealed by the pattern of sky brightness, the sky being slightly brighter in that half containing the sun. Yet it is difficult to be at all satisfied with any of the attempts to find environmental cues which would be adequate as a basis for the navigation of migrants and yet which lie within the sensitivity range of the known sensory mechanisms.

Turning then to the other horn of the dilemma, we find a variety of ingenious theories hung up on formidable objections from the point of view of the sensory physiologist. Best known, perhaps, is the idea that birds have the equivalent of a magnetic compass—that they can perceive the earth's magnetic field in some manner and guide their migrations accordingly. This theory has assumed many forms. Some postulate that birds can tell the direction of magnetic north, while others argue that they can judge the intensity of the earth's field, or the horizontal or vertical components in it. One of the most elaborate theories holds that birds can sense the angle of dip in the lines of force constituting the earth's magnetic field. The numerous but quite unconfirmed reports that birds' navigation is affected by the electromagnetic waves from radio transmitters are usually linked to the theories of magnetic sensitivity, though not in any precise manner.

The tendency of these theories is to postulate that the birds are aware of two effects, one of which informs them of their latitude and the other of their longitude. The migration is conceived of as a movement resulting from some type of simple reaction or "tropism" (automatic orientation) of which even one-celled protozoans are capable. By assuming sufficiently sensitive receptors, one can thus picture the



GOLDEN PLOVERS of America and of the Pacific migrate tremendous distances over water. In America, young plovers fly south to winter range by way of Mississippi Valley and Brazil; adults fly 2,000 miles over Atlantic by way of Lesser Antilles. Pacific plovers make even longer ocean flights from Siberia to New Zealand.

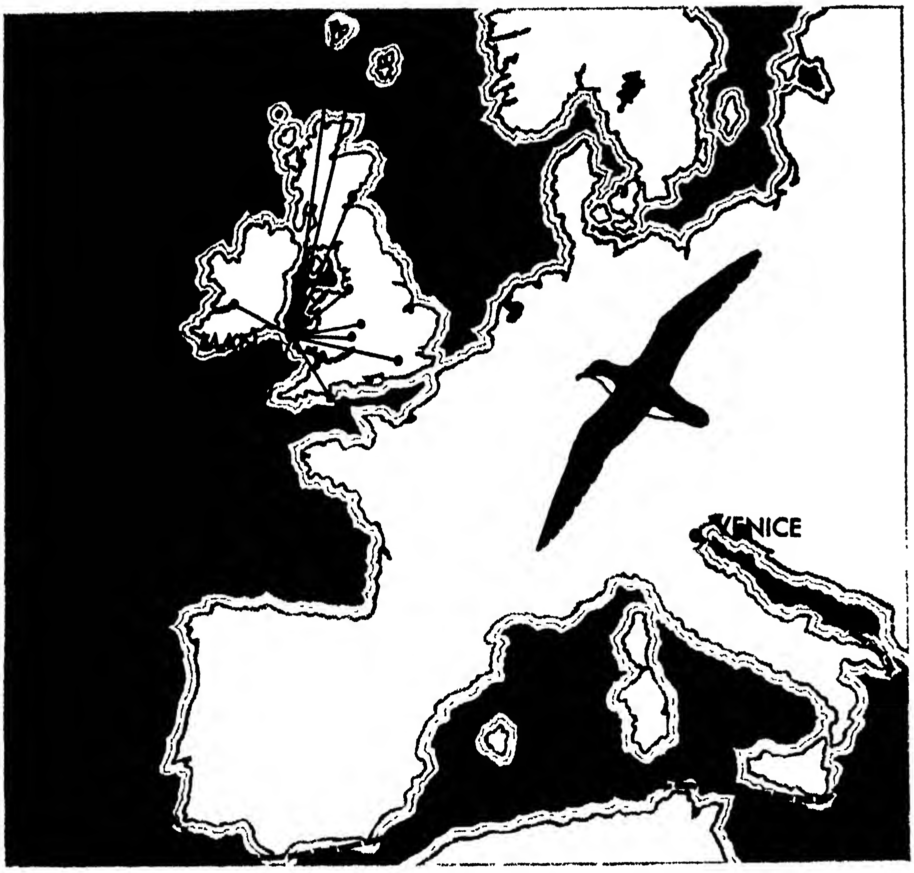
actual reactions of the birds in very simple terms. But these theories must face the fact that no one has shown that birds can sense a magnetic field as weak as the earth's, any more than we can ourselves. Birds have been subjected to very intense magnetic fields in the hope that they would exhibit some response—indicating that they felt the magnetism. But no such response has ever been demonstrated, and we must therefore discard the magnetic theories unless and until such a sensitivity can be shown.

A really new theory was advanced recently, namely that birds orient themselves by means of mechanical forces arising from the earth's rotation. These forces might take many forms, such as 1) an increase in the apparent weight of a flying bird depending on the direction of its flight, 2) a lateral force exerted on fluids flowing through its arteries, or 3) the so-called "Coriolis force," which causes a body traveling with uniform velocity through the air to trace a slightly curved path over the earth's surface, owing to the fact that while the flying object is in the air the earth rotates underneath it. These effects are of a type which might be within the range of a bird's sense organs, since they involve mechanical accelerations for which the bird has specialized receptors in the inner ear labyrinth. But the difficulties in the way of a bird's being able to make quantitative distinctions in such effects are enormous. The variation in weight is only one part in several thousand, and it could easily be masked by the much larger accelerations resulting from flight itself, to say nothing of the slightest turbulence of the air, or even the bird's own breathing and heartbeat. Similarly, the lateral forces on arteries are infinitesimal compared with the effects of turbulence within the blood and the waves of pulse pressure traveling from the heart. Thus this hypothesis seems scarcely more plausible than the magnetic theories.

ONE reason for our persisting ignorance concerning the sensory basis of bird navigation is the difficulty of making detailed observations of an individual bird while it is actually setting its course. One can watch wild birds leave their breeding grounds; one can observe them passing various points on their way south; one can note the time of arrival and departure of a species in any region; and by observing where the birds are concentrated during migration one can map with fair accuracy the chief routes traveled. But birds can seldom be followed from the ground for more than a mile or two, and such observations disclose birds flying in all directions even during the height of a migration. Thus one can very seldom be sure that at a given moment any particular bird is actually starting a migratory flight in the correct direction. Birdbanding—the fixing of numbered metal bands about the legs of birds—has demonstrated the extent of many individual journeys, but for our purposes this method suffers from several limitations: the percentage of recoveries at significant distances from the point of banding is extremely small, and almost invariably several weeks or months elapse before the birds are recovered at a distance, so that one has little assurance from the results of banding alone that a bird traveled directly from the point of banding to the point of recovery. Nor can one tell anything of the route followed, or the conditions under which the migration was performed, much less the sensory mechanism employed.

Direct experiments with migrating birds are extremely difficult, but some have been performed, notably by William Rowan in Canada and Werner Rüppell in Germany.

Rowan kept young crows in captivity in Alberta until November, when all wild



HOMING EXPERIMENTS show wild birds' remarkable ability to find way back to nests. Here Manx shearwaters were released at various distances from home in Wales. One bird returned from Venice by sea route in 14 days.

DIRECTIONAL SENSE of birds is illustrated in famed crow experiment. Crows which normally summer northeast of Rossitten were trapped during migration and released at Flensburg. Their summer range was displaced.

crows had left the area for their winter range 1,000 miles or so to the southeast. Then the young crows were banded and released with a widely publicized reward for their recovery, dead or alive. Several were shot and reported within the next few weeks. All of those that had traveled any distance were recovered within 30 degrees of the normal migration route. This showed that young crows could take the correct direction without adults to guide them.

Rüppell's experiments involved a European species of crow which could be captured in large numbers during spring migration on the Baltic coast of East Prussia. In his most clear-cut experiment some 500 crows were captured at Rossitten on the Baltic and released 465 miles to the west at Flensburg, a locality which this population of crows had never visited previously. The normal summer range of these crows, as revealed by the recovery of many birds banded over a period of years, was an area northeast of Rossitten. When the crows displaced to Flensburg were retaken during the following spring and summer, all recoveries came from the area to the northeast of Flensburg; in other words, the crows had shifted their summer range westward. Evidently these crows continued their spring migration in roughly the normal direction even though they were displaced into different territory.

SUCH experiments with migrating birds are valuable, but they are also very laborious. One still does not know much about the actual routes flown by individual birds, nor is there much opportunity for direct experimentation. Another procedure has therefore been widely used to study bird navigation. It is a sort of artificial migration which can be arranged experimentally in many species by catching adult birds at their nests, while they are incubating eggs or caring for young, and transporting them to a distance before release. Birds treated in this way often return hundreds of miles, behaving somewhat like homing pigeons. These artificial homing experiments, as they are called, bring one a step closer to the direct observation of the individual navigating bird. Here one knows at least the beginning and end points of the journey; by watching the nest, one can observe the bird's return and accurately measure the total elapsed time for the homing flight.

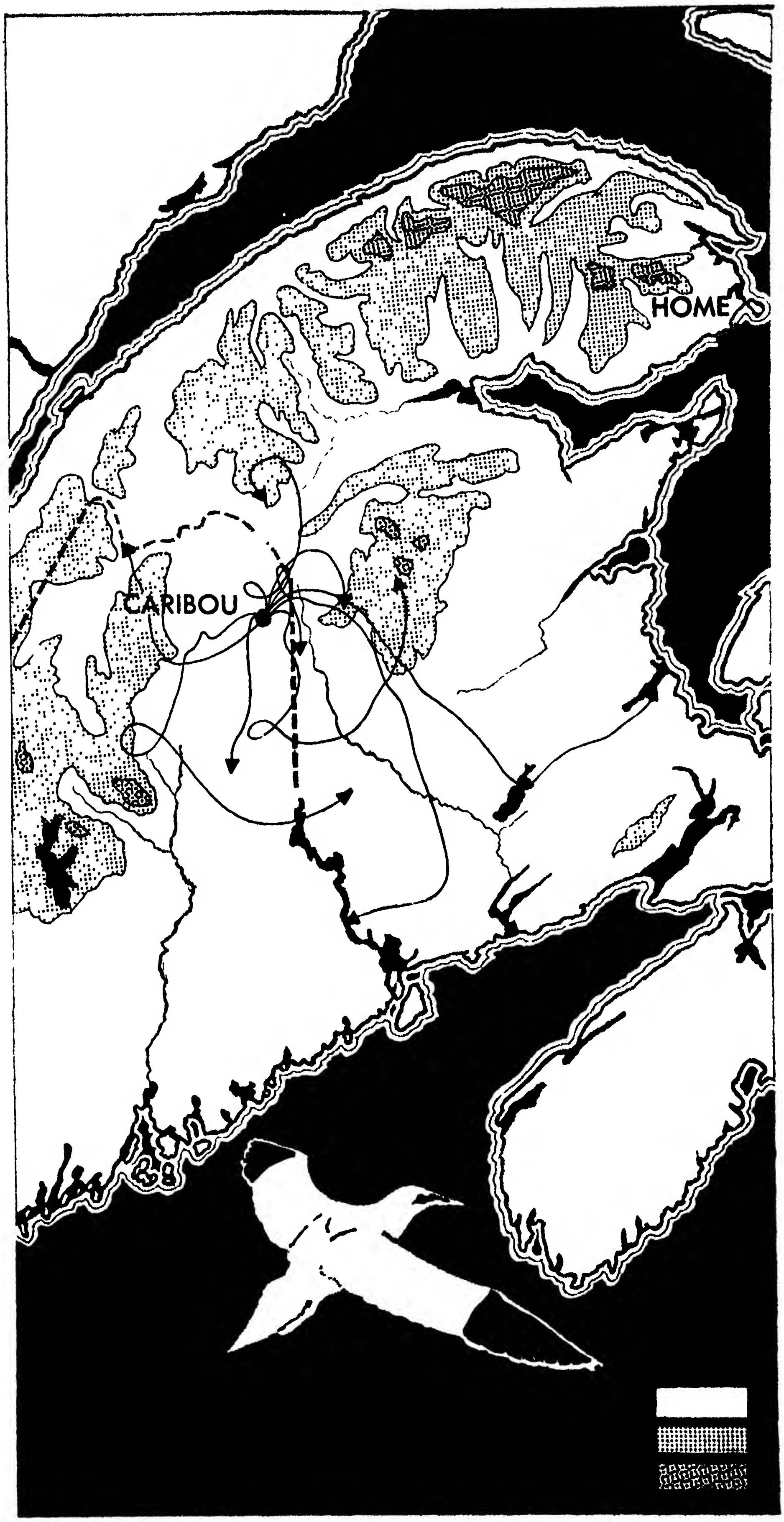
The homing performances of various wild birds in these experiments seem almost as spectacular as their natural migrations. The first experiments of this type were those of John Watson and Karl Lashley with noddy and sooty terns (*Anoüs stolidus* and *Sterna fuscata*) nesting near Key West, Florida. Some of these birds returned even when carried 855 miles northwest to waters where these two species are seldom seen. More recent experiments have involved swallows (*Hirundo*

rustica) which returned 1,200 miles from Greece and Spain to nests near Berlin. In another series of experiments, four out of six herring gulls (*Larus argentatus*) nesting on the Massachusetts coast returned from Chicago, 870 miles inland. The most startling case is that of a strictly marine species—the Manx shearwater (*Puffinus puffinus*)—which returned in 14 days from Venice to its nest on an island near Wales. Presumably it flew all the way over water (since shearwaters are almost never seen inland), using a roundabout route of at least 3,700 miles by way of the Mediterranean, the Straits of Gibraltar and the Atlantic.

So striking are these homing performances of wild birds that they have been widely cited as experimental evidence for the theories of special sensory mechanisms—evidence which to many has seemed fully as important as the natural migrations. Thus the magnetic theorists describe the behavior of a homing bird as a return towards the latitude and longitude of the home area by the simple following of gradients in the magnetic sensations. This theory does not appear to be supported by experimental test, however, for when small magnets are attached to a homing bird or when it is exposed to a strong magnetic field its performance does not seem to be affected.

Certain other studies of homing birds have led to an unexpected conclusion: that when released in really strange territory birds are not able to head directly home but explore wide areas, often flying in quite the wrong direction until they reach territory which they have visited before and where they can presumably find familiar landmarks to guide them home. Birds do not return as quickly or in as high percentages from unfamiliar territory as from equally distant areas which they have visited before. Moreover, the average speed of return in homing experiments is far below the birds' known velocities of flight. Even allowing considerable time for resting and feeding along the route, there remains time for wide deviations from the straight line connecting the release point and home. Occasional spectacular cases like that of the shearwater released at Venice would be expected as a result of chance; significantly, a second shearwater carried to Venice did not return until a year later.

To test the hypothesis that birds find their way home by exploration, it was necessary to learn something about the actual routes they flew. By learning to fly light airplanes, Raymond J. Hock and I were able to achieve this objective. We managed to follow a group of gannets (*Morus bassanus*) in the air for a considerable part of their homing flight. Gannets are sea birds, feeding on fish. A large number nest on Bonaventure Island in the Gulf of St. Lawrence. Their large size and white color render them easily visible from the



ACTUAL FLIGHT PATHS of homing gannets released at Caribou and followed in airplane show that birds explored in all directions before finding correct direction to their island nests, where they eventually arrived safely.

air. Several were transported about 215 miles west southwest from the island and released on fresh water near Caribou, Me. They were surrounded by completely unknown territory: to reach their nests they had to fly for at least 100 miles over land. Yet they displayed a homing ability quite comparable to that of other wild birds. Those released at Caribou averaged almost 100 miles per day during the return flight. The significant advance over previous homing experiments was our ability to follow the return routes of eight of the seventeen birds released at Caribou for periods as long as nine and a half hours and distances as great as 230 miles. The map on page 23 shows the initial portions of these eight return routes, and I think that the exploratory nature of the flight paths is clear.

One naturally asks whether the presence of the airplane did not cause the birds to behave abnormally. The gannets showed no fear of the plane even when it was within 500 feet; at least they did not turn away from their previous course at our approach, as many birds do when an airplane comes near. Nevertheless we kept 1,500 to 2,000 feet above the gannets during these observations in order to minimize the chances of influencing their choice of route. But the best indication that the airplane did not disturb the gannets was that the homing performance of a control group which was not followed was almost exactly the same with respect to average speed and percentage of returns as the performance of the eight birds we observed from the air. If the airplane influenced or frightened the gannets, it did not prevent them from returning to their nests at the normal speed.

These observations seem to confirm several lines of indirect evidence that the homing ability of both wild birds and domestic homing pigeons is based largely on visual landmarks, or on exploration when the birds are released in unfamiliar territory. Such a conclusion leaves us in something of a quandary. The homing experiments argue strongly that birds do not possess any special sensory mechanism that can guide them home or inform them of their latitude and longitude. Yet in the case of natural migrations it is preposterous to suggest that the birds are merely exploring. Even young birds without guidance begin their first migration in roughly the correct direction, as shown by the experiments of Rowan and others. Individual young birds may deviate 20, 30 or even 40 degrees from the average direction for the species, but virtually none go north in the fall.

There remains the possibility that migratory birds can determine the direction appropriate for a particular migration. But this is of no help when they are artificially transported into unknown territory, for then they cannot know whether home lies north, east, south or west. If this be

GANNETS NEST on Bonaventure Island in the Gulf of St. Lawrence. Taken to unfamiliar territory in Maine, birds flew hundreds of miles over land to return to their home.

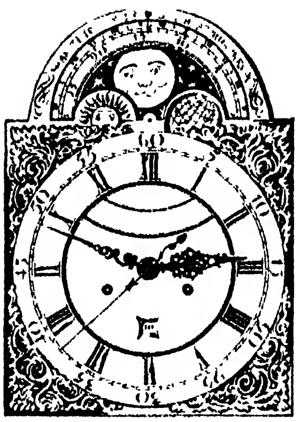
true, then clearly the homing experiment would not reveal the basis of navigation by migrants. For this reason, among others, the best hope for future progress seems to be offered by experiments with actual migrations, particularly if the routes flown by individual birds can be traced as we were able to trace the routes of homing gannets.

The late Werner Rüppell, who was the leading European investigator of these phenomena until his death during the war, originally postulated that the homing of wild birds depended upon a mysterious and unidentified "sense of direction." But in his last paper, describing the experiments with migrating crows which I have cited previously, Ruppell suggested that the position of the sun might be the guiding cue. Such a theory is certainly rendered more plausible by the recent demonstration of the Austrian zoologist Karl von Frisch that bees locate sources of food with reference to the position of the sun in the sky [SCIENTIFIC AMERICAN, August].

These questions cannot be settled without specially devised experiments, which should include prolonged following of individual birds from the air and a close correlation of the birds' behavior with meteorological data. For instance, it would be most valuable to learn whether birds begin a migratory flight in the correct direction under heavily overcast skies when no celestial objects are visible. The fact that birds are observed migrating under such conditions is not conclusive evidence, for the overcast may be a local one and the birds might have started their flight 50 or 100 miles away under clear skies, holding their course in thick weather by means of local cues such as topography or wind direction.

The novelty and the expense of airplane observations of individual birds have prevented such work from being undertaken on any extensive scale, but I hope that the increasing practicability of light airplanes (and eventually helicopters) will serve as a stimulus for such work in the future. Perhaps we can look forward in the next few years to the emergence of a group of air-minded ornithologists who will trace significant portions of the migration routes of individual birds with a simultaneous understanding of the ocean of air in which they move. Such research, wisely conducted and on an adequate scale, might well provide the key to these ancient and baffling questions.

Donald R. Griffin is associate professor of zoology at Cornell University.



SCIENCE AND

"Atomic Storage Battery"

A NOVEL idea for an "atomic storage battery" which conceivably could be used to drive automobiles was suggested in a recent speech by Lewis L. Strauss of the Atomic Energy Commission. Atomic power has been considered out of the question for small vehicles because it has been assumed that the power would have to be provided by a chain-reacting pile, requiring bulky shielding. But Commissioner Strauss suggested that radioactive isotopes might be used as a portable source of power. They would be produced in a central-station pile and put up in containers to generate heat wherever desired.

A similar idea was advanced two years ago by George Gamow, the George Washington University physicist, in his book, *Atomic Energy in Cosmic and Human Life*. He proposed using for this purpose radioisotopes which give off only non-penetrating alpha or beta radiation. They would need no other shielding than their own container and thus would provide a compact heat source.

Atomic storage batteries would be a wasteful utilization of atomic energy, however. Radioisotopes cannot be turned on or off at will, but decay continuously; the storage battery, therefore, would run on whether or not it was in use. Moreover, isotopes are produced in a pile only at the expense of other pile reactions. Each neutron used in forming a radioisotope means one neutron less for forming fissionable material or for the fission reaction itself. And the energy yield of the alpha- and beta-decay processes is at most a hundredth (usually much less) of the yield of the fission process.

Another Meson

AS the investigation of mesons proceeds, the picture seems to become more complicated instead of clearer. At least five of these atomic particles have already been generally accepted by nuclear physicists. They are the positive and negative mesons of mass 200 times that of the electron, positive and negative mesons of mass 300 and a neutral meson of mass 88. Some physicists think there is also evidence for the existence of three other varieties—positive, negative and neutral mesons of mass 800 to 1,000. Now the discovery of still another meson is reported. E. G. Cowan of the California Institute of Technology has announced evidence for a particle with a mass of about 10—by far the lightest meson yet found.

In a Wilson cloud chamber photograph of the results of cosmic-ray collisions with atoms, made in a plane at an altitude of 27,500 feet, Dr. Cowan noticed a highly unusual track. The amount of ionization indicated that it was that of a meson, yet the particle had been markedly deflected in collisions with two electrons, indicating that it was extraordinarily light in weight. Dr. Cowan's calculations from its angle of deflection give 11.5 as the upper limit of its mass. Its charge is unknown; the photograph yielded no information on that point.

Chemical Trends

TWICE a month the American Chemical Society publishes a compact journal, *Chemical Abstracts*, which might be considered the Domesday Book of chemistry. Sooner or later practically everything in scientific literature of interest to chemists is summarized in its pages.

E. J. Crane of Ohio State University, its editor, surveys his journal every few years to analyze trends in chemical research. His latest canvass has yielded these interesting facts:

Germany has dropped precipitously from a position of leadership in chemical research (which is no great surprise); its output of scientific papers is only one sixth of what it was before the war. The leading nation is the U.S., which accounted for 40 per cent of all chemical research reported last year. Next were the British Empire and the U.S.S.R., each producing roughly an eighth of the world total of published papers. India is in eighth place; its chemists are making as many contributions as the chemists of all of South America.

During 1947 some 30,000 papers were abstracted, as compared with 46,000 in 1938. This drop represents not a decrease in research, but a change in its character. The single researcher is being replaced by the team, which prepares fewer but more comprehensive papers. The individual abstracts are now one third longer on the average than they were 10 years ago.

Major changes have also taken place in the relative importance of different branches of chemistry. Papers on organic chemistry now outnumber inorganic papers by four to one. Within organic chemistry, the greatest relative increase has come in research on cellulose.

Nobel Awards

THE Nobel prizes for 1948 in medicine, chemistry and physics have been awarded to:

Medicine: Paul Mueller, research chemist for the Swiss pharmaceutical firm of J. R. Geigy Co., for discovery of the insecticidal powers of DDT.

Chemistry: Arne Tiselius of the Institute of Physical Chemistry, Upsala University, Sweden, for his invention of an apparatus to separate complex mixtures of proteins, such as blood, and for other discoveries in biochemistry.

Physics: Patrick Maynard Stewart Blackett of the University of Manchester, England, for improvement on the Wilson cloud chamber and for cosmic ray research.

Geological Institute

AN American Geological Institute is being formed by 11 scientific societies in the field of geology. It will represent the earth sciences in the same way that the recently formed American Biological Institute represents the biological sciences.

The Geological Institute will maintain an information center and serve as a point of contact between the geological professions and the government. It will be affiliated with the National Research Council. Among the 11 founding societies are the Geological Society of America, the Mineralogical Society of America, the American Association of Petroleum Geologists, and the American Institute of Mining and Metallurgical Engineers.

Television for Farm Areas

TELEVISION is growing much more rapidly than radio at a comparable stage 25 years ago. By next summer there will be transmitting stations in most large cities and receiving sets in nearly two million homes. But the short range of television transmitters, which currently have an effective radius of only about 25 miles, remains a serious limitation.

The publicized attempts to extend the radius of transmitters by rebroadcasting from high-flying planes have not been particularly successful so far. A recent effort to telecast a football game from a plane flying over Cleveland, for example, was a failure.

Another approach has been suggested to the Federal Communications Commis-

sion by Kenneth A. Norton of the Bureau of Standards' Central Radio Propagation Laboratory. Norton said that interference could be reduced and coverage greatly increased by systematic spacing of stations and by requiring all stations on a given channel to use the same amount of power and antennas of the same height.

Norton suggested that each station use 100 kilowatts of power and a 1,000-foot antenna, and that stations on the same channel be located 280 miles apart in an equilateral triangle. According to studies by the Central Radio Propagation Laboratory, such an arrangement, with the triangles properly overlapped, would make it possible to cover the principal rural areas and most metropolitan centers without interference.

Fertilizer for Fish

IN response to the twin pressures of world food needs and severe overfishing in many areas, fishery experts are now advocating the wide use of fertilizer to speed up the growth of fish. About two years ago a Scotch biologist fertilized a closed-off arm of the North Sea with superphosphate and sodium nitrate. The fertilizer greatly increased the plant food supply and the number of fish.

Similar experiments have been conducted with fresh-water fish by Earl F. Kennamer of the Alabama Polytechnic Institute. Kennamer seeded two one-acre Alabama ponds with bluegill bream. One pond was fertilized at two- to four-week intervals with 20 pounds of a nitrogen-phosphorus-potassium mixture. The other pond, not fertilized, was used as a control. At the end of the season, the treated pond yielded 200 pounds of fish averaging four to six ounces apiece—a good size for this species of pan fish. The control pond, on the other hand, yielded only 40 pounds of fish averaging one ounce each. Thus at a cost of roughly $20 for fertilizer the yield of fish was increased fivefold.

X Disease

A NEW disease about which so little is known that it is called X Disease by Department of Agriculture veterinarians is killing many cattle. It was first recognized in a dairy herd in upstate New York in 1939 and now has been found in 32 states. About one third of the animals in diseased herds become sick; 60 per cent of these die.

The first recognizable symptom is a thickening and hardening of the skin, whence the disease was first called hyperkeratosis. The mouth, tongue, throat and stomach soon become badly inflamed, with the result that the animals cannot eat. Death usually occurs in a few weeks. Only the Pacific coast states are free of the disease. Beef cattle are affected more often than dairy animals. No cure is known. The cause is suspected to be a nutritional imbalance or a poison in commercial fertilizers.

X Disease does not compare in economic destructiveness with brucellosis or mastitis. Its cost to farmers is probably no more than $4 million a year. But its rapid spread during the past decade makes it a serious threat for the future. The Department of Agriculture has started an emergency research program to identify the cause and find a cure.

Technology and Cancer

BRITISH researchers in cancer have long believed that the rise of this disease is not due simply to improved diagnosis or the aging of the population, but is in part a result of industrialization. They place the blame on new materials used in modern technology and industry which can produce cancer. This view is now gaining acceptance in the U.S., partly as a result of a U.S. Public Health Service study two years ago which proved that lung cancer was a specific hazard of the chromate industry.

Last month, accordingly, the National Cancer Institute initiated a comprehensive new program of research on this problem. It established an Environmental Cancer Research Laboratory at the Georgetown University Medical School. Other studies in the program are under way in Ohio, New Jersey and New York, where a joint Occupational Cancer Committee has been set up by industry and the state government.

The list of suspected carcinogens among modern materials is long. In addition to chromates and petroleum hydrocarbons, it includes nickel carbonyl (a widely used catalyst), arsenicals, asbestos, benzol, amines, creosote and other wood-tar products, and dye intermediates. Many other materials may also be carcinogenic. Charles S. Cameron, medical director of the American Cancer Society, told a meeting of the Society last month that it "cannot be categorically denied that pollution of the air by smoke, chemically treated water supplies and other artificial impediments of modern living may increase the incidence of cancer."

Mission to Liberia

DURING the late war the President of Liberia, William S. Tubman, asked President Franklin D. Roosevelt for American help in improving the health of the Liberians. At the time large numbers of American troops were stationed in or passing through Liberia en route to the North African front. Roosevelt responded to the appeal by sending a U.S. Public Health Service mission. Senior Surgeon John B. West, the mission chief, has now reported on the results of the mission. The report is a demonstration of what can be accomplished by even a small group of experts in a so-called backward tropical country.

In three years, the mission effected a virtual revolution in Liberia's health. At the time of the mission's arrival, Liberia, with a population of two million, had a total of about 200 hospital beds, six doctors and four nurses with first-class training. Some of the hospitals were without a physician. Only two rubber company hospitals were reasonably well equipped. The annual government appropriation for public health was only $40,000. Malaria, venereal disease and helminthiasis (an intestinal worm disease) were widespread.

The mission concentrated its first efforts on Monrovia, the capital, near which was located the major American air base. An intensive DDT-and-drainage program reduced the incidence of malaria by nearly 95 per cent. By cutting the fly population in half, it also lowered the incidence of intestinal disease. A simple chemical treatment all but wiped out helminthiasis. The success of the attack on veneral disease so impressed the Liberian Government that it appropriated funds for compulsory periodic examinations and free treatment for the entire population.

The mission organized the first clinical laboratory Liberia had ever had. It launched a program to train Liberians in mosquito control. The U.S. State Department sent a mission to start nursing education. These educational activities grew into the Tubman National Institute of Medical and Allied Sciences. Because there are few college graduates in Liberia, the courses are geared to the needs of high-school graduates. Although the program is far below European or American standards, it has proved an effective stepping-stone between jungle witchcraft and modern medicine. Meanwhile, the mission has sent back to American laboratories for study a steady stream of specimens of tropical disease.

Meetings in January

SOCIETY of Automotive Engineers. Annual meeting. Detroit, January 10-14.

American Physical Society. New York City, January 27-29.

A PURE ENZYME is isolated as crystals. The crystals shown here are pepsin, the enzyme that breaks down proteins in the stomach. The laborious process of isolating a few such crystals was first accomplished in 1930 by J. H. Northrop of the Rockefeller Institute at Princeton, N. J. Here they are enlarged 180 diameters.

ENZYMES

They are the catalysts of life. Long known for their ability to turn sugar into alcohol, they engineer a host of other biochemical reactions

by John E. Pfeiffer

SOME three million of your red blood cells die every second. Or, to look at it another way, three million red cells are born every second, because the body continuously calls up reserves to keep the total count the same. The entire red-cell population is replaced in about three months, and cycles of birth and death turn even faster among the molecules in the plasma of the blood. Cell-free plasma contains countless protein molecules, every four weeks all of them have disappeared. They have been broken down and new molecules have been rebuilt at the precise rate needed to keep the body functioning efficiently.

This rapid molecular turnover goes on in relatively solid tissues as well as in the circulating blood. Deposits of fat, which were once believed to serve as warehouses for the storage of food reserves, are more like department stores during the Christmas rush. They seethe with biochemical activity, decomposition and synthesis neatly balancing each other so that within a few months entirely new fat deposits are created. The same goes for connective tissue, tendons and ligaments, blood-vessel walls, muscles. Swift changes occur even in the bones as the links of molecular chains are split and welded again in the ceaseless round of metabolism.

These facts, many of them determined by the modern technique of labeling molecules with isotopic tracers, were not known to earlier biologists. They conceived of the body as a machine. Food was the fuel, and the energy of combustion kept the machine going. All of this took place within tissues that had to be repaired from time to time as they wore out. Otherwise they were relatively firm and unchanging structures. When the body was active, of course, it needed extra resources of energy, but during rest metabolism idled until the next spurt of activity. Biologists now know that the actual situation is far different: living things must work ceaselessly merely to exist.

So life is more like a whirlpool than a machine. There is nothing machinelike about the vortex formed when water spirals downward In one sense, an entirely new whirlpool comes into being every few seconds as the rotating center replenishes itself from the surrounding waters. But through it all the form does not change. The position of the vortex, the space it occupies, the shape of the spinning funnel, preserve their integrity over long periods of time; the system has an identity and structure of its own Similarly the human body and every other organism known to be is a vortex of continual change.

Yet the cycles of breakdown and synthesis proceed in the face of an apparent paradox. The great majority of biochemical reactions do not take place spontaneously. When they are tried in laboratory glassware, most chemical constituents of life combine or decompose at a rate far too slow for the pace of metabolism. The average protein must be boiled for 24 hours in a solution of 20 per cent hydrochloric acid to be thoroughly broken down. The body does the same thing in four hours or less, and without high temperatures and strong acids.

The phenomenon that makes life possible is catalysis—the action of certain substances that speed up chemical reactions thousands of times without themselves being changed. Industrial chemistry uses catalysts in the cracking of petroleum, in the synthesis of ammonia, and in many other processes; organisms use them to help build tissues and to degrade foodstuffs to simpler materials, as in the case of the four-hour breakdown of proteins. The catalysts of life are called biocatalysts, or enzymes, and the rise of biology has come with an increased understanding of what they are, what they accomplish, and how they work.

Enzymes are unaffected by the reactions that they work; they are destroyed only by wear and tear or poisoning. They operate in amazingly small concentrations. A single cell has been estimated to contain about 100,000 enzyme molecules to accelerate its 1,000 to 2,000 chemical reactions—an average of only about 50 to 100 molecules for each process. A single molecule of the enzyme that splits hydrogen peroxide into water and oxygen (and creates the white foam when the antiseptic is placed on a wound), can transform more than 5 million peroxide molecules a minute. Other enzymes transform from 1,000 to more than 500,000 molecules in the same time.

Investigation has shown that these biochemical middlemen play a significant role in every vital process. They are key substances in the photosynthetic reactions that build plant tissues from water, carbon dioxide and sunlight. Enzymes turn leaves red and yellow in the fall, make the freshly cut surface of an apple or potato brown, convert grape juice into wine, and grain mash into whiskey. But the chemical processes in which they participate are so obscure that it has taken centuries to elucidate a few fundamental principles, and every month new facts are published which promise to alter many currently accepted ideas. Although perhaps as much as three quarters of our knowledge has come within the last 40 years, some of the first scientific studies of enzymes were made in the 18th century in connection with the study of digestion.

Early Advances

Until early in the 18th century men believed that the digestive system was a kind of meat grinder that accomplished digestion by contracting vigorously and rubbing food particles together. This was disproved when the French scientist René de Réaumur made a falcon swallow pieces of meat enclosed in a perforated metal tube to protect them from stomach friction. When Réaumur pulled the tube up a few hours later, he found that the tube was intact but that the meat had been digested. Lazaro Spallanzani, an Italian physiologist, performed roughly similar experiments on hawks—and later on himself!—using wire cages instead of tubes. In a treatise published in 1780, he suggested

that food is decomposed by substances in the gastric juices. One of the substances was found to be hydrochloric acid. In 1835, the German physiologist Theodor Schwann discovered a non-acid substance in gastric juice which he called "pepsin." But although it had been named, pepsin was still a chemical mystery.

The next advance in enzyme research came 25 years later, when the French Government commissioned the great Louis Pasteur to investigate a national catastrophe: the mysterious souring of entire batches of fine wine. Pasteur showed that the souring never took place under sterile

DE RÉAUMUR (1683-1757) fed falcons meat in tubes to show friction was not the only agency of digestion.

conditions; he proved that it was a "disease" caused by bacteria that produced lactic acid. This work led him to a thorough investigation of the entire process of alcoholic fermentation, first in wine and later, after France had been defeated in the war of 1870, in beer, to benefit "a branch of industry wherein we are undoubtedly surpassed by Germany." Pasteur discovered that fermentation was "life without oxygen": the work of yeast cells digesting sugars for their own nourishment.

Pasteur was a vitalist, believing that biological phenomena were the result of non-physical forces, and he went beyond the evidence of his experiments. The experiments informed him that living cells were capable of producing fermentation; from this he jumped to the incorrect conclusion that *only* living cells could accomplish it. On the basis of this theory Pasteur established two categories: 1) "organized ferments," the live organisms whose metabolic processes yielded alcohol, and 2) "unorganized ferments," lifeless substances like pepsin that could be isolated from living cells.

This terminology, plus a lack of exact knowledge as to the chemical nature and action of ferments, led to much confusion. Some biologists argued that substances like pepsin should not be called ferments because the name properly belonged to yeast cells and other microorganisms. Others twisted the argument another way. Yeast cells were not ferments, because all organisms, including man, harbor intricate chemical processes, and surely a man was not a ferment!

In 1878, to provide at least a semantic solution to the controversy, the German physiologist Willy Kühne suggested the new name "enzyme." Literally translated, the word means "in yeast," but Kühne suggested it for unorganized ferments, the substances that had already been known to exist apart from yeast. Thus until 1897 biologists had two words—"enzymes" for substances such as pepsin, and "ferments" for the processes in the living organism.

Then the distinction, and many of the vitalists' arguments, were broken down by a lucky accident in the laboratory of Eduard Buchner, another German scientist. Buchner wanted to determine whether cell-free yeast extracts had any medical value, and to obtain such extracts he had to kill the yeast organisms. First he ground yeast cells to a pulp in a mixture of quartz sand and fine abrasive. Then he put the material in a canvas bag and subjected it in a special hydraulic press to pressures up to 7,500 pounds per square inch. Finally he collected the juice that trickled out.

At this stage of the work Buchner was not concerned with ferments, enzymes or scientific debates. His problem was to preserve the extract for lengthy experiments with laboratory animals. One of the methods he attempted was adding large amounts of sugar to the extracts. This failed to produce the result he wanted. In fact, the mixture soon reacted to form alcohol; fermentation occurred in the absence of living yeast cells. This accidental finding ultimately won Buchner a Nobel prize. It demonstrated that there was no longer a need for the two words ferment and enzyme. They were the same.

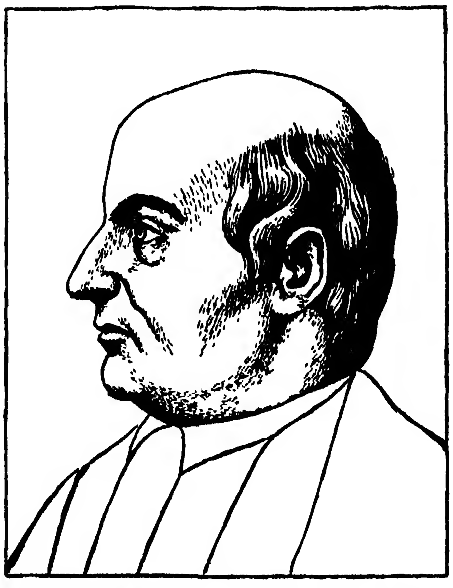
But Buchner's experiment did not satisfy the vitalists. For 30 years some of them continued to dispute Buchner's findings. The vitalists also found new arguments in other experiments; enzymes are often entangled with philosophy. Ironically, one of the most ingenious and painstaking biochemical experimenters, Richard Willstätter of Munich, did as much to obscure as to clarify the nature of biocatalysts. Again it was chiefly a matter of concluding too much from too little.

The German investigator set out to determine the chemical structure of enzymes. Colloidal particles such as enzymes adhere to finely divided powders of China clay and other substances. By patiently filtering and centrifuging such powders and their attached particles, Willstätter succeeded in obtaining relatively pure enzymes. But his method was wasteful; to isolate one enzyme he began with about 20 pounds of brewer's yeast and lost 91 per cent of the enzyme it contained in the process. His final solutions were so dilute that experiments to reveal the nature of the purified enzyme yielded only negative results. Yet, sadly, the negative findings were used to draw positive conclusions.

Willstätter did not know—and apparently he did not consider the possibility—that certain substances are biologically active at concentrations of one part in a thousand million million. Their identification lay far beyond the sensitivity of his chemical tests. So Willstätter announced that enzymes were substances of a composition unknown to chemists. In 1925 one of the leading enzyme texts took up the theme in a section called "Enzymes Not Proteins" and, citing the German findings, went on to indicate that they were not carbohydrates or fats either. Conclusions of this kind were pleasing to the vitalists, but they were of little help in the further understanding of enzymes.

"The First Enzyme"

Yet the year after the textbook was published the first enzyme was obtained in pure form and identified chemically. For nine years James B. Sumner of Cornell University had worked to isolate an enzyme from the jack bean. The enzyme was urease, which decomposes the metabolic

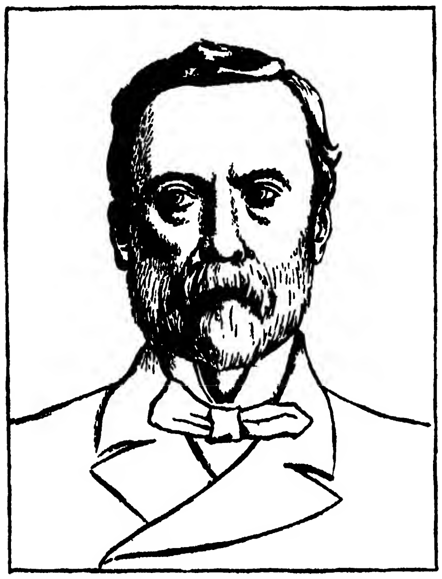


SPALLANZANI (1729-1799) swallowed meat in tiny cages to prove that it was digested by gastric juice.

waste product, urea. Urease, like many other enzymes, is named after the substance on which it acts. Willstätter's results had often been cited to persuade Sumner that he should choose a more promising project, but the work went on despite occasional financial pinches and inadequate equipment. (In those early days Sumner used an old-fashioned coffee mill to grind the beans, and a window

ledge as a refrigerator.) The problem was to find a solvent that would dissolve urease and not other chemicals, and a substance that would then precipitate the enzyme.

The final process was, in Sumner's words, "absurdly simple." One day in April of 1926 he mixed jack-bean meal with acetone, a solvent that had been suggested by his former biochemistry professor at Harvard, and allowed the solution to filter overnight. Next morning he examined a drop of the filtrate under the microscope and saw something he had not seen before—tiny octahedral crystals.



PASTEUR (1822-1895) found that yeast cells were responsible for fermenting batches of fine French wine.

Then he centrifuged the crystals out of solution, concentrated them and found that the new solution possessed very strong urease activity. That afternoon Sumner telephoned his wife with the news that was to win him a Nobel prize 21 years later: "I have crystallized the first enzyme."

Urease turned out to be a protein with a molecular weight of 483,000. (One unit of molecular weight equals the weight of one hydrogen atom.) Despite Willstätter's bitter disagreement, the fact was confirmed. Researchers finally had positive evidence that the elusive substances they were attempting to purify were proteins.

But there is no single process for the crystallization of all enzymes. Aside from the useful guide that the experimenter should work with large amounts of material, at least several grams and several hundred grams if possible, each enzyme calls for special chemical techniques. Urease, once the correct procedure had been found, was easy to isolate. But to purify pepsin John H. Northrop of the Rockefeller Institute for Medical Research in Princeton, who with Wendell M. Stanley of the same institution shared the 1947 Nobel prize with Sumner, needed a far more complex process. He announced the method in 1930, nearly a century after pepsin had been named by Schwann.

The process began with a dilute preparation of crude pepsin, and involved five exceedingly sensitive precipitations. The delicacy of the technique was dictated by the very nature of proteins. Each protein is built up of amino acids, which come in 20-odd varieties and are relatively simple in structure. The proteins they form, however, are the most complex molecules known to chemistry. Amino acids can be hooked to one another in millions of different ways. They may form long structures called peptide chains, but biochemists have not yet learned the exact arrangement of the links in the chains or of the chains in the protein molecule. The magnitude of the problem is indicated by the fact that a single molecule of the pancreatic hormone insulin contains more than 400 amino-acid units, while other proteins contain as many as 125,000.

One of Northrop's chief problems was to precipitate proteins without destroying them. Protein molecules may exist as tiny spheres wrapped around by peptide chains, as amino acids strung out in delicate branches, or as a latticework of crisscross strands. Since protein structures are maintained by a balance of electrical forces between atoms, a slight chemical shift in their environment may distort them into tangled masses which cannot be restored to the original patterns—which happens when an egg is boiled and the white coagulates.

This "denaturing" is one of the pitfalls in the crystallization of pepsin. Northrop's successful precipitation technique was used at the Rockefeller Institute in Princeton by Wendell M. Stanley to isolate the tobacco-mosaic virus, and by M. Kunitz to crystallize several enzymes. Of the 40-odd enzymes isolated to date, all are proteins.

The Work of Enzymes

The fermentation of sugar, yielding alcohol, is an admirable illustration of the detailed chemical processes engineered by enzymes. In the days when Buchner thought his cell-free yeast juice contained the single enzyme zymase, the glucose-to-alcohol reaction was represented by the following uncomplicated formula:

$$C_6H_{12}O_6 \xrightarrow{\text{zymase}} 2\,CO_2 + 2\,CH_3CH_2OH$$

This is a chemical statement to the effect that one molecule of glucose, catalyzed by zymase, yields two molecules of carbon dioxide and two of ethyl alcohol. But if fermentation were such a single-step process, it has been calculated, most of the resulting energy would appear as useless heat. Actually fermentation directly involves at least 12 enzymes—and it took hundreds of research workers from more than a dozen countries to unravel nature's scheme for altering glucose.

The molecule of glucose is built around a chain of six carbon atoms, the splitting of which is a crucial step in the fermentation process. Before this step can be taken, however, glucose must be suitably prepared for its destruction. Three enzymes transform glucose for the splitting, and nine more are involved in the remaining steps which lead to ethyl alcohol. This outline of the process is a poor reflection of the detailed chemical processes that propel it. These are presented in greater detail by the drawing on page 34.

This splitting of the carbon chain of glucose involves one of the most significant of all biochemical cycles. It requires a large amount of chemical energy, and the source is adenosine triphosphate, or ATP. The energy is obtained from one of ATP's potent phosphate groups, indicated by the two right-hand Ps in the following simplified formula:

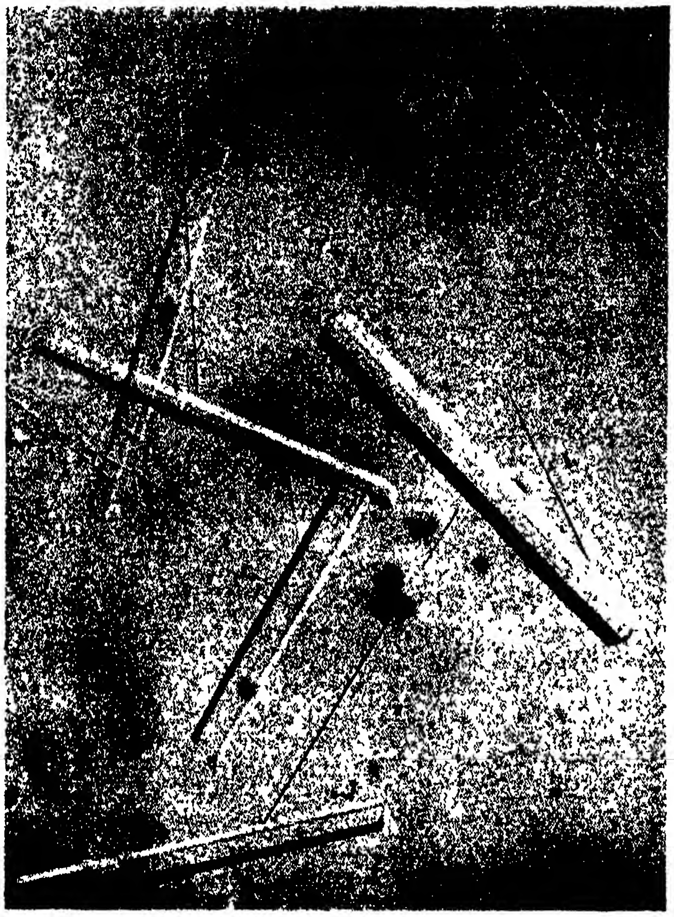
$$\text{Adenosine}—P \sim P \sim P$$

The two right-hand phosphate groups are attached by chemical bonds which yield 12,000 calories of energy when they break. (The left-hand group yields only 2,000 calories.) The bonds may be considered a sort of "cement" of electrons holding the phosphate groups. Oscillating back and forth at high speed, the electrons endow the phosphate groups with an extra reactivity. The specific usefulness of ATP is that enzymes can transfer its phosphate groups to other substances—along with the energy of their oscillating bonds.

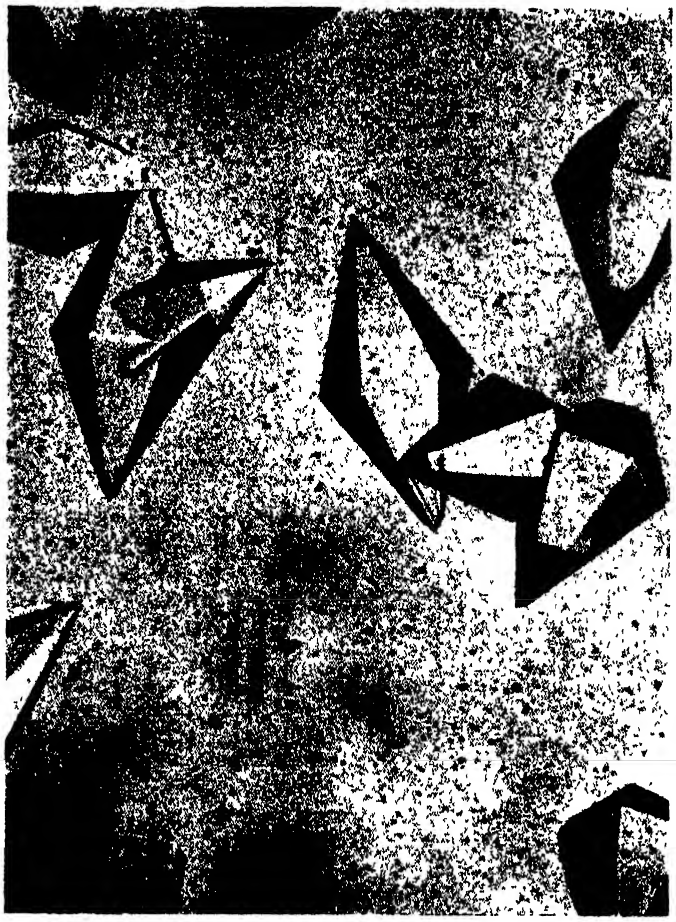
The energy that drives the cycles of fermentation is first obtained by splitting off the right-hand phosphate group and attaching it to glucose; this step, catalyzed by the enzyme hexokinase, leaves adenosine diphosphate (ADP) and a glucose phosphate which is catalyzed to a fructose monophosphate. Transforming this latter substance to fructose diphosphate means splitting another section from another ATP molecule.

BUCHNER discovered in 1897 that lifeless juice of yeast cells had power to ferment sugar to ethyl alcohol.

At this stage the process leaves two ADP molecules wandering about with



HEXOKINASE, an enzyme involved in the fermentation of sugar, was crystallized in 1946 by M. Kunitz and M. R. McDonald of Rockefeller Institute in Princeton.



ACETYL PEPSIN is a modified form used in the study of pepsin activity. It was crystallized in 1934 by R. M. Herriott and J. H. Northrop of Rockefeller Institute.

missing groups. Unless they are rebuilt as ATP, the entire cycle will grind to a stop. The deficit is made up during the next steps of fermentation when the six-carbon chain is finally split and two inorganic (non-ATP) phosphates are taken up into an intermediate compound. These inorganic phosphates, however, are low in energy content, and ATP will only accept the high-energy variety. The cell therefore uses an enzyme called triosephosphate dehydrogenase to remove two hydrogen atoms, which transform low-energy phosphates into high-energy phosphates.

The potent phosphate groups are then split off by another enzyme and attached to the two dismembered ADP molecules, forming ATP. The energy supply is thus sustained—but the cell does better than that. During the next stages two extra high-energy phosphate groups are created and passed back to other ADP molecules. This bonus may be used to accelerate fermentation or to provide the energy needed for the growth and reproduction of yeast cells.

There is still one biochemical loose end. During the manufacture of high-energy phosphate bonds, two hydrogen atoms have been lost. These are picked up by a special hydrogen carrier called coenzyme I. This substance now cannot participate in later reactions and, again, the entire cycle would break down unless it included a mechanism for freeing coenzyme I of its hydrogen. The opportunity comes at the very last step of fermentation, after pyruvic acid has been converted to acetaldehyde and carbon dioxide. Carbon dioxide goes off as a gas. Acetaldehyde, which remains, is just two hydrogen atoms short of being ethyl alcohol, the final product of the fermentation. The missing atoms are naturally presented by the hydrogen-bearing coenzyme I, and the latter is restored to perform its function.

Enzymes and Muscles

This completes the fermentation process and some of its interrelated systems. Ethyl alcohol can then be taken internally and used to interfere with human enzyme systems. Incidentally, for every 99 parts of ethyl alcohol, yeast produces one part of fusel oil, a mixture of various higher alcohols which is not only responsible for most of the flavor of liquor but also for hangovers.

While some biologists traced the intricate cycles of fermentation, others studied the mechanism of muscle. Gradually, first from fragments of evidence and finally from an imposing structure of knowledge, both groups began to realize that the workings of yeast and muscle cells were very much alike. In fact, the processes that change malt and hops to beer, and those that provide the energy for an Olympic sprinter have 14 steps—and 11 of the 14 are exactly the same for the two types of process. The workings of the great ATP cycle and the wheel-within-a-wheel coenzyme I cycle are the same in both cases. One important difference is that in muscle contraction pyruvic acid is broken down to lactic acid instead of ethyl alcohol. The lactic acid is then carried by the bloodstream to the liver, where the reverse of the 14-step process builds it into animal starch, or glycogen. (Muscles cannot utilize glucose.) Another important difference is that the breakdown of glycogen yields three instead of two "bonus" ATP molecules. Muscles attain an efficiency of 60 per cent or better, as compared with the 50 per cent efficiency reached in modern steam turbines.

ATP not only supplies energy in muscle contraction, but also plays an important role in the workings of the nervous system. Nerve cells build up one of their essential chemicals, acetylcholine, with the aid of the enzyme choline acetylase, and the synthesis requires energy from ATP. Recent studies at Johns Hopkins University suggest that ATP is also the energy source for the reaction that enables fireflies and other organisms to produce light. That it may also be associated with the enzyme systems necessary for the movement of single-celled organisms is indicated in at

GAMMA CHYMO-TRYPSIN is one of several enzymes produced in the pancreas that have function of breaking down proteins. It was crystallized in 1938 by M. Kunitz.

RIBONUCLEASE is another pancreatic enzyme that has the specific function of breaking down a protein in yeast. It was crystallized in 1940, also by M. Kunitz.

least one case, the wriggling of sperm toward the unfertilized egg.

How They Function

Water is the medium for the majority of biochemical processes. In water the molecules of life are in ceaseless thermal motion, occasionally reacting when they collide with one another. Essentially the function of an enzyme is to increase the rate of reaction. In a solution without enzymes the chance that a molecular collision will result in a reaction may be a trillion to one. If the appropriate enzyme is present, the probability will be much increased. To use the gambling term, enzymes lower the odds. The question is how they perform this mathematical feat by chemical means.

Any explanation of the phenomenon must account for certain experimental facts. One of the most obvious is that a given enzyme does not speed reactions among all the molecules of protoplasm. If this were the case, the result would be biochemical chaos. Actually enzymes are highly specific, producing reactive collisions only among the molecules of selected compounds. These compounds are generally known as substrates.

A spectacular example of enzyme specificity involves molecules that are made up of exactly the same atoms in different structural arrangements. Such close chemical relatives are known as isomers. In 1860 Pasteur discovered that tartaric acid, a by-product of wine fermentation, exists in two forms. When a beam of polarized light was transmitted through crystals of tartaric acid, some crystals turned the plane of polarization to the right, while others turned it to the left by exactly the same amount. Since both types of tartaric acid are identical in chemical composition, the difference must be in the arrangement of their atoms.

It has been shown that such pairs of crystals—called dextrorotary and levorotary—are found among many compounds, and are related to one another as an object to its mirror image or as a right-hand to a left-hand glove. Enzymes can make the subtle distinction between isomers. The muscle enzyme lactic dehydrogenase, for example, acts on levorotary lactic acid but has absolutely no effect on its mirror image, dextrorotary lactic acid.

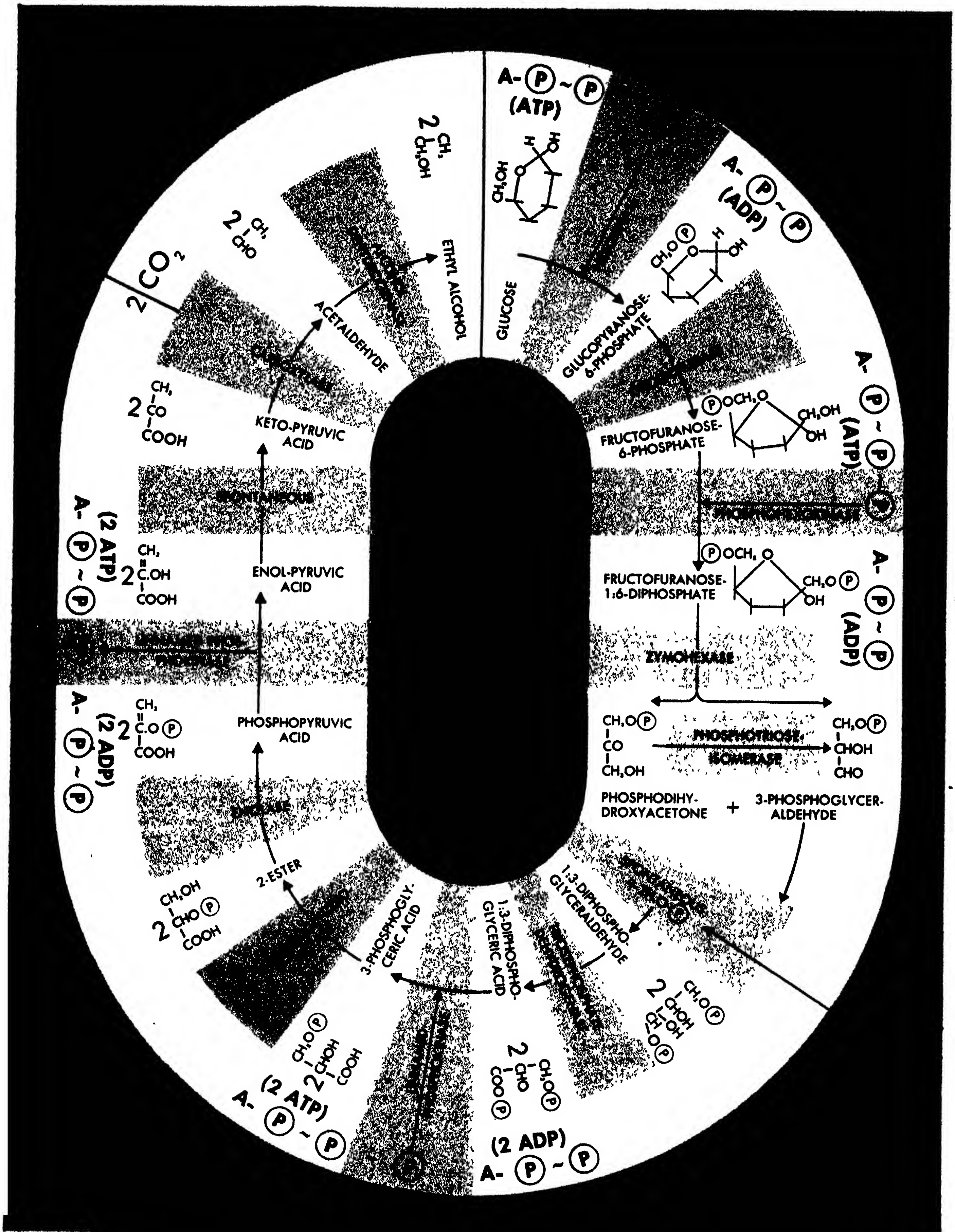
Some enzymes are even more selective. The so-called hydrolytic enzymes, as an example, are involved in the following general type of reaction:

$$A—B + H_2O \longrightarrow AOH + BH$$

Here A—B represents a molecule consisting of two parts connected by a chemical linkage. Some enzymes will break down any molecule with a particular linkage regardless of the nature of the linked structures, others demand not only the right linkage but also the right part, say the B structure. Still other enzymes, the most specific of all, operate only on molecules that satisfy the three-way requirement that both the A and B parts and their linkage must be of a particular kind.

A more detailed explanation of what specificity means is furnished by the phenomenon of competitive inhibition. The enzyme succinic dehydrogenase catalyzes the breakdown of succinic acid and nothing else. Its effectiveness is considerably reduced, however, if malonic acid, the structure of which closely resembles that of succinic acid, is added to the solution. Experiments show that malonic acid, while not being changed itself, apparently attaches itself to the enzyme and takes it out of circulation by occupying a position on its molecule that would normally be filled by succinic acid. In other words, malonic acid seems to compete with succinic for an active region of the enzyme molecule.

These and other experiments suggest an attractive analogy to explain specificity. It is a theory which some protein chemists label "philosophy," although they concede that philosophy can be useful. The enzyme molecule can be visualized as a "lock" with notches and indentations of a particular pattern; the substrate molecule, in this case succinic acid, is the



GLUCOSE-TO-ALCOHOL cycle involves 14 known steps and 12 enzymes. Latter are indicated in brown. Opening steps attach phosphate groups of adenosine triphosphate (ATP) to glucose, leaving adenosine diphosphate (ADP). Cycle also takes in other phosphates (*arrow at lower right*), finally surrenders all of them to rebuild two extra ATPs from ADP. Cycle in center carries hydrogen atoms until they are needed in last step.

"key," and its configurations mesh into the enzyme pattern. Malonic acid, a very similar key, will fit the lock, but not perfectly. The fit is good enough to keep out succinic acid, but not good enough to unlock the door—hence the door stays closed. Perhaps the most brilliant experimental evidence for such a concept, adduced by E. S. G. Barron and his associates at the University of Chicago, involves three closely similar substances: acetic acid, monofluoroacetate and monochloroacetate. The only difference among them is that one hydrogen of acetic acid is replaced by a fluorine atom in monofluoroacetate, and by a chlorine atom in monochloroacetate. The effect of this substitution is shown in the drawing at the bottom of page 37. The links between each of the three atoms and the rest of the molecule to which they are attached are of different length. For hydrogen the link is 1.09 Angstrom units (one Angstrom unit equals one hundred millionth centimeter); for fluorine it is 1.41 A.; for chlorine it is 1.76 A.

An enzyme catalyzes the oxidation of acetic acid (a process involved in fat metabolism) and presumably its molecule contains "notches" into which the acid fits. The addition of monofluoroacetate to the solution completely inhibits the oxidation, meaning that this compound also fits the enzyme molecule. Monochloroacetate, however, appears not to fit, for it has no effect on the enzyme's ability to oxidize acetic acid. In other words, the tiny difference in length between the link of the fluorine-containing inhibitor and that of the ineffective chlorine compound (.35 A., or about 1/762,000,000 inch) is enough to prevent a sufficiently close lock-key fit.

Fitted Molecules

The lock-key theory implies that there is some sort of fleeting union between enzyme and substrate, an implication which has been backed by many experiments. As a matter of fact, the spectroscope has permitted biologists to "see" the union taking place. This was attempted for the first time 12 years ago by Kurt G. Stern, then at Yale University. Using the enzyme catalase and a hydrogen peroxide derivative as substrate, he observed first the spectral light pattern characteristic of catalase and then a new pattern, presumably that of the enzyme-substrate union. A short while afterward, however, the original catalase spectrum appeared again, indicating that the enzyme had performed its duty and was ready for more work.

What is the purpose of the brief combination of an enzyme with its substrate? The answer to the question hinges on a fact mentioned earlier: that not all collisions between molecules produce chemical reactions. In a 100-cubic-centimeter solution of ethyl bromide and diethyl sulfide, for instance, there are 1.6×10^{34} (16 million billion billion billion) collisions a second, but fewer than one out of every billion billion collisions results in a chemical reaction. The reason for this low proportion of successful hits is that molecules are relatively stable structures, and most of them bounce off each other a bit jarred but essentially unscathed.

Now enzymes do not increase the speed of molecules in solution, nor do they increase the frequency of collisions. Instead they increase the number of fruitful collisions by weakening the structure of substrate molecules so that they react more readily. In combining briefly with its substrate (in the case of catalase the combination lasts less than one 85,000th of a second), an enzyme somehow distorts the architecture of the substrate molecule, converting it from a relatively stable to a highly reactive state. There is evidence that in some cases this effect is achieved by removing electrons and transforming the substrate molecule into a charged ion.

Chemical changes, however, do not necessarily take place simply because a substrate molecule has fitted itself into its enzyme mold and has been activated. With certain enzymes like pepsin, to be sure, this two-molecule union seems to be sufficient for completion of the substrate-converting process. But more often than not a third substance that is not a protein is an added requirement. Catalase, peroxidase and other enzymes seem to have such accessory substances more or less permanently attached to their proteins. These substances are therefore called "prosthetic groups." Many enzymes, however, apparently require only that the accessory substances be available in solution as so-called coenzymes. This field of inquiry is one of the most active and controversial in enzyme research, and the entire question of enzyme auxiliaries needs considerable clarifying. This much is known: in most enzyme processes the protein alone is not enough to speed chemical reactions. Unless coenzyme I is present in the alcohol fermentation system previously described, the process breaks down, and many other coenzymes have been discovered.

Taking a three-way, enzyme-coenzyme-substrate reaction as a case in point leads to the following rough sketch. The enzyme and its substrate combine in such a way that the molecular structure of the substrate is distorted sufficiently to increase its susceptibility to change. Almost simultaneously the enzyme may attract a coenzyme molecule to one of its unoccupied parts. A reaction between coenzyme and substrate may then occur, forming new compounds. Finally the temporary union breaks up, and the enzyme molecule is free for further action. Something of this sort happens during the first step of alcoholic fermentation, when the enzyme hexokinase synthesizes glucose phosphate from glucose and ATP. Both of these molecules are attached to a hexokinase molecule in such a position that one of the high-energy phosphate groups is transferred from ATP to glucose. Then the three-cornered union flies apart, leaving ADP, glucose phosphate and an unchanged enzyme.

Enzymes and Hormones

Even more obscure than the mechanism of enzyme action are the factors that control enzyme reactions. What is it that determines when and how quickly enzyme activities shall take place in nerve cells, muscle cells and all of the other specialized units that make up the higher plant and animal organisms?

There is reason to believe that hormones play an important part in controlling and coordinating the workings of enzyme systems. The most significant finding along these lines was made about two years ago by W. H. Price, Carl Cori and S. P. Colowick at Washington University in St. Louis. They discovered that hormones play an essential part in the enzyme system that maintains the balance between sugar in the blood and glycogen in the liver. There is a delicate equilibrium between the hormone insulin, which tends to lower the amount of sugar in the blood by promoting the storage of glycogen in the liver, and a presumed diabetogenic hormone secreted by the pituitary gland, which promotes the metabolism of glycogen and hence tends to raise the concentration of sugar. Diabetes may be the result either of too little insulin or too much of the pituitary hormone. The Washington University group suggested that this upset in hormone balance was directly connected with hexokinase, the same enzyme that initiates alcoholic fermentation.

Hexokinase is utilized in the liver to add a phosphate group to glucose, a preliminary step essential to the storage of sugar. The pituitary hormone, however, inhibits hexokinase activity. Whether it is overproduced or insulin is underproduced, the effect is the same: a relative excess of the diabetogenic hormone, subnormal storage of glycogen in the liver, and rising sugar levels in the blood. The discovery of this process is one of the first connections established between hormones and enzymes. Other hormones, including those that produce dwarfs and giants, probably influence growth and metabolism in a similar manner.

Such speculation brings us again to the notion of enzymes that can be inhibited and activated. Does the diabetogenic hormone inhibit hexokinase by providing substances that occupy strategic parts of the enzyme molecule and thus prevent it from working on its normal substrate? And does insulin counteract the inhibiting effect by removing these substances and "unmasking" the enzyme? Only further investigation can answer these questions, but it is known that the unmasking effect plays a significant role in the control of enzyme action during many biological processes. For example, pepsin, the func-

tion of which is to digest proteins, does not enter the stomach ready to act; it is secreted by the stomach walls as the inert substance pepsinogen, which is promptly converted to pepsin by the hydrochloric acid of the gastric juices. The conversion is accompanied by a drop in molecular weight from 42,000 to 38,000, and this may be interpreted as the removal of a protein fragment that masks pepsin action.

An example of mass unmasking is familiar to embryologists. An unfertilized egg cell is fully prepared for the most spectacular burst of biological energy known. It contains structural materials, ATP as a source of energy, and hundreds of enzymes that will engineer the building of a tree or a man from a tiny blob of protoplasm. The enzymes, however, are blocked, probably by specialized coatings, until fertilization takes place. Then, by an unidentified mechanism, the blocking substances are dissolved, hundreds of reactions are set off at once, and the cell begins to grow and divide.

Enzymes in Health and Disease

The patient investigation of enzyme action and enzyme control has brought added insight to a whole constellation of biological and medical problems. Enzymes not only speed the vital processes of the developing egg, but play a fascinating part in the act of fertilization. An unfertilized egg is protected by a tough coating of cells cemented with a substance called hyaluronic acid. The sperm carries the enzyme hyaluronidase specifically to break up the barrier and penetrate within.

There is evidence that the single sperm which accomplishes fertilization does not contain enough of the enzyme to break down the barrier by itself, and that the unsuccessful sperm cells must contribute their hyaluronidase. This explanation accounts for the fact that perhaps millions of sperm are necessary for fertilization, although only one penetrates the egg. Working on the theory that some cases of human sterility may be due to a lack of hyaluronidase, some physicians have recently administered extra amounts to a few selected patients and, according to preliminary announcements, normal pregnancy has resulted. Whether or not this simple treatment proves effective in a significant number of cases, any successful treatment for sterility will require an intimate understanding of the enzymes concerned.

Enzymes have also been identified with the toxins of infectious diseases. Thus *Clostridium welchii*, the rod-shaped organism most commonly found in gas gangrene, releases an enzyme called lecithinase. This destroys red blood cells by disintegrating the substance lecithin in their walls. (The same lecithinase is one of the poisons in cobra and rattlesnake venom.) The germ also liberates an enzyme that dissolves the protein connective tissue of muscle, and the "gas" of gas gangrene is produced by a group of enzymes that accelerate a pathological form of fermentation. The effects of many drugs and poisons are similarly tied up with enzyme reactions. Prostigmine, which is used in treating several diseases that paralyze muscles, strongly inhibits the enzyme cholinesterase. Strychnine also acts on cholinesterase. Cyanide affects cytochrome oxidase.

The chemical study of certain coenzymes has had unexpected medical consequences. In 1932 it was found that an essential part of the coenzyme I molecule was nicotinic acid, and three years later C. A. Elvehjem and his associates at the University of Wisconsin identified the substance as the anti-pellagra vitamin. Other vitamins definitely known to be part of coenzyme molecules include B-1, B-2 and B-6. Whether all vitamins are parts of coenzymes remains to be seen, but the possibility is particularly strong for those factors of nutrition that are needed in "trace" quantities. In amounts of less than one ten millionth of an ounce the new B-12 factor is sufficient to produce measurable rises in the blood counts of anemia patients.

Vitamins are as necessary to some harmful bacteria as they are to human life. This fact has opened the way for putting the competitive inhibition of enzymes to medical use. The possibility was discovered by accident after the introduction of sulfa drugs, though for a long while their effectiveness in curbing germs was a mystery. Then it was observed that the ability of the drugs to inhibit the growth of bacteria was considerably reduced in the presence of para-aminobenzoic acid (PAB), a member of the vitamin B complex and an essential factor in the growth of many organisms. A comparison of the molecular structures of sulfanilamide and the acid soon indicated the reason for the phenomenon.

Germs that need the vitamin presumably incorporate it into their metabolic processes as part of a coenzyme, and things go beautifully until sulfanilamide comes upon the biochemical scene. This sulfa drug is a very close chemical relative of PAB, which is the secret of its medical effectiveness. The resemblance is so close that the bacterium cannot tell the difference and takes up sulfanilamide as if it were a real food factor. By the time the mistake is discovered, the false "vitamin" has been drawn into the enzyme system and jammed the works.

Antivitamins

Sulfanilamide, the first "antivitamin," was discovered accidentally, but new drugs may be discovered by a planned offensive against this Achilles heel of bacterial metabolism. There is already quite a list of antivitamins (*see drawing on page 39*). There is also some evidence that the polio virus needs vitamin B-1, and the discovery of a B-1 antivitamin that would inhibit the virus without irreparably damaging cells is another possibility that awaits further research.

The part played by vitamins and other accessories in enzyme action also throws new light on the importance of trace elements in plant and animal life. In 1895 thousands of sheep on Australian ranches were dying of "bush sickness." Since the disease closely resembled anemia, ranchers tried feeding the animals large doses of iron. The treatment worked in some cases and not in others, the difference depending on the source of the iron.

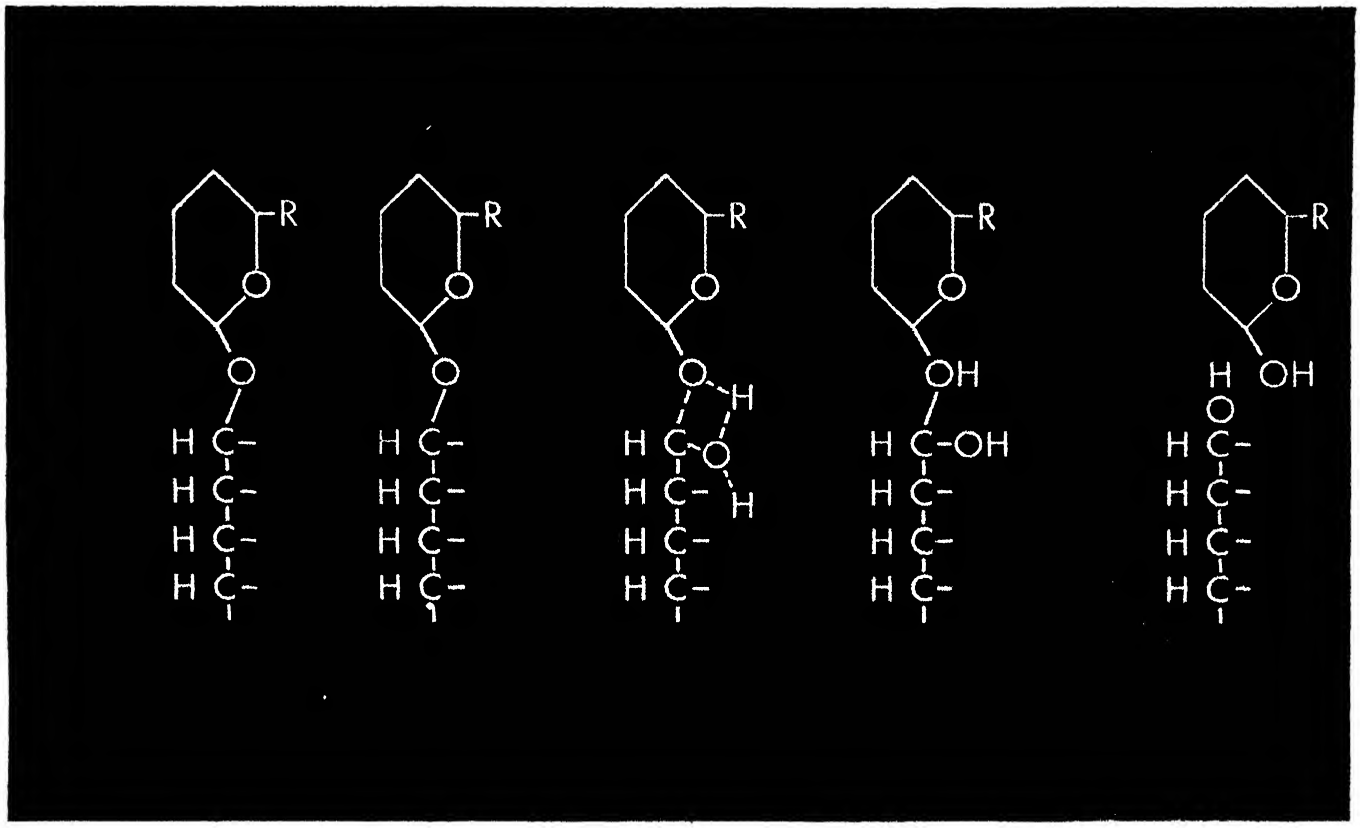
So the Australian Government imported iron ores from all over the world and compared the samples. After a series of elaborate analyses, it was found that the iron which helped to cure bush sickness contained tiny amounts of cobalt. A sheep's daily requirements were calculated, and it was found that about a millionth of an ounce of cobalt was enough to prevent the malady.

The need for such elements may be connected with the efficient working of enzyme systems, for many enzymes are known to contain or to require the presence of metallic elements in small amounts. One of the key steps in alcoholic fermentation involves an enzyme called enolase, which requires the presence of magnesium ions before it can take effect. Hexokinase, similarly, cannot work without magnesium.

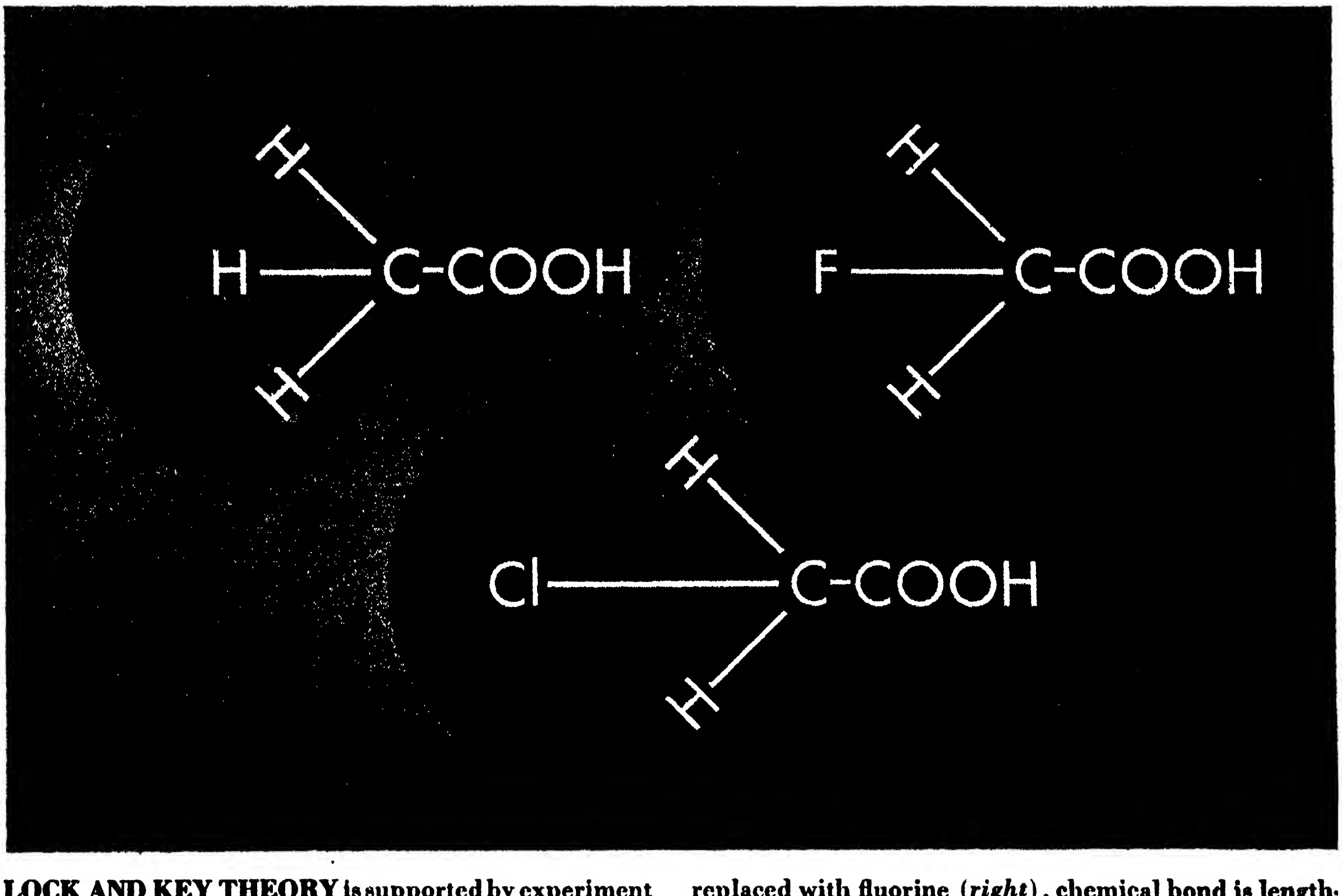
Industrial Uses

Enzymes have still other practical applications. By breeding improved strains of microorganisms and investigating their enzymes, research workers have increased the efficiency of alcoholic fermentation in the beer, wine and liquor industries. The fermentation process can also be redirected to produce industrial chemicals. Liquor chemists developed various biological methods to help relieve the severe fat shortage in Germany during the war. The Germans found that the addition of sodium bisulfite prevented yeast from transforming glucose into alcohol and detoured the process to yield glycerin. This they used in the manufacture of soap and explosives. The current potato surplus may provide extra work for bacterial enzyme systems which can break starches down to simpler compounds. An example of the latter is butyl alcohol, an industrial solvent and one of the chemicals utilized in producing synthetic rubber.

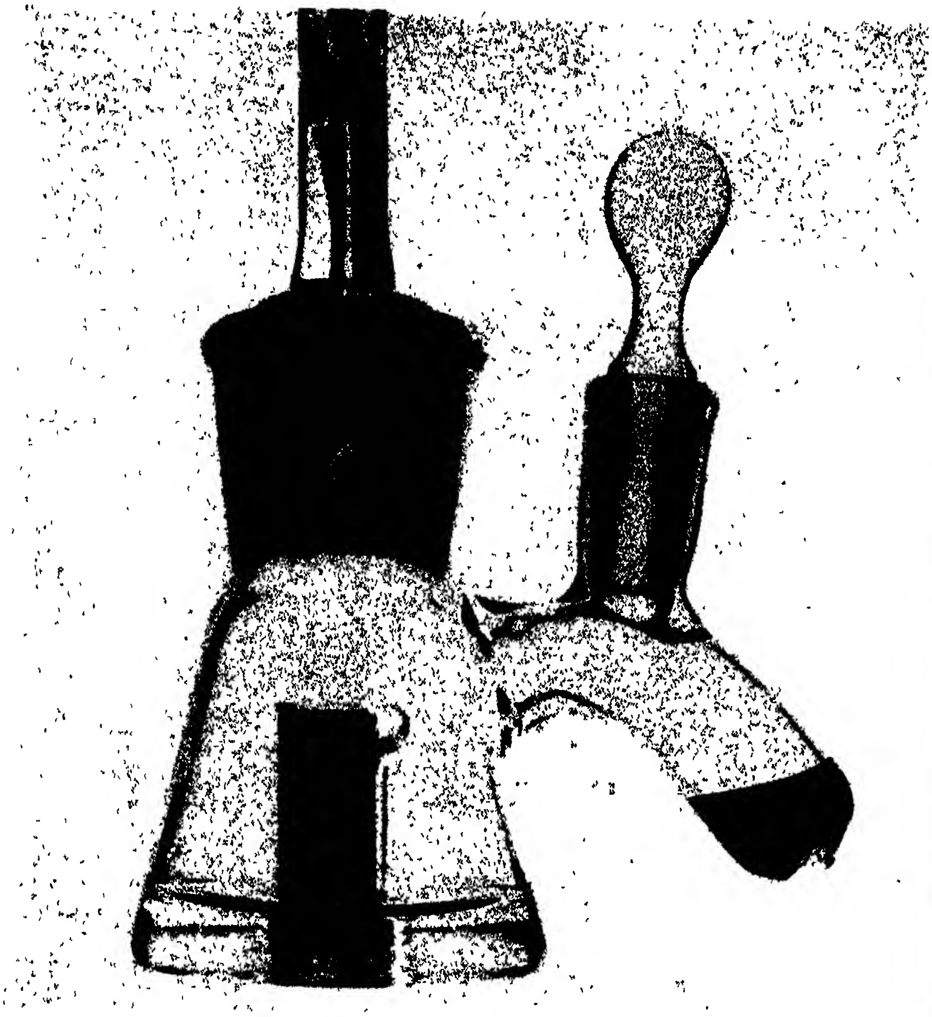
Enzymes are also used to obtain heating gas, fertilizer and many other valuable materials from sewage and industrial waste. They tenderize meat, tan leather, turn cornstarch into syrups and sugars, and help in the making of dozens of products in the cosmetic, textile and baking industries. There is even an enzyme-containing spot remover, based on the theory that protein-destroying enzymes might be effective in dissolving stubborn egg stains.



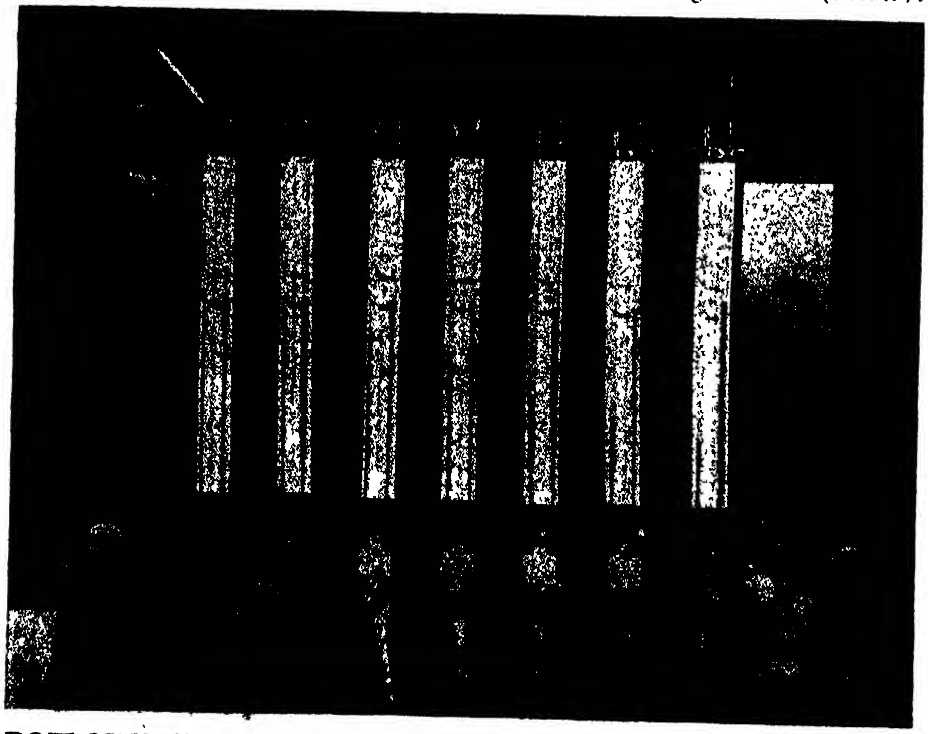
HOW ENZYME MAY WORK is illustrated by theoretical example. Here the enzyme, drawn in black, has two active parts. These fit the molecule on which they act (1). When they combine with the molecule (2), they deform it in such a way (3, 4) that it is broken down into two molecules (5), in this case a sugar and alcohol.



LOCK AND KEY THEORY is supported by experiment involving three similar compounds. An enzyme works on acetic acid (*left*). When one hydrogen atom of acid is replaced with fluorine (*right*), chemical bond is lengthened but enzyme still works. When enzyme is replaced with chlorine (*bottom*), the enzyme no longer works.



WARBURG APPARATUS is an important tool of enzyme research. The cup above, which is part of the apparatus, contains substrate at the bottom and enzyme at right. The two are mixed after warming in bath (*below*).



ROW OF MANOMETERS, each attached to a cup of the type shown above, moves from side to side as cups are shaken in warm bath. Manometers then measure the amounts of gas taken up by the enzyme reactions in the cups.

TWO MANOMETERS show amount of gas taken up by reaction in short time. Note drop in right manometer.

From the lofty perspective of science the fundamental problem is not industrial utility or even the artful crystallization of pure enzymes. The most challenging question is how the human body, or any organism, manufactures enzymes. An enzyme is a protein built up by the body from amino acids and peptide chains. If we assume that an enzyme may be synthesized as simply as possible, it is created when two protein fragments are pieced together by a single enzyme. If that is the process, how is the ultimate enzyme itself synthesized?

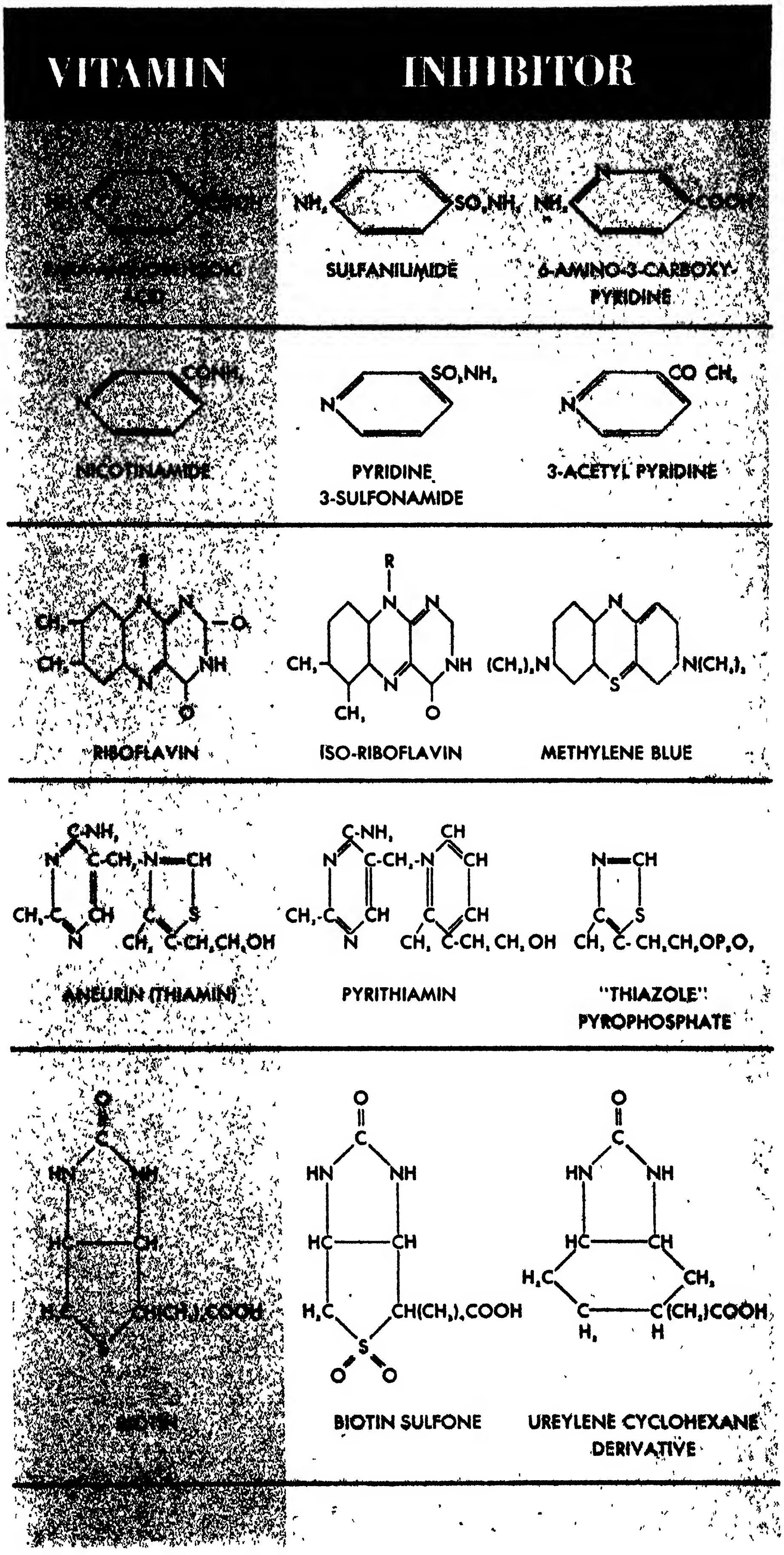
The only way of surmounting the difficulty is to assume that certain molecules are capable of forming exact replicas of themselves. This is to say that they act as enzymes for their own synthesis. This is reproduction at the molecular level. Genes, the units of heredity, have been assumed to be such substances. Viruses likewise are autocatalytic. There is some speculation that genes are the ultimate enzyme-makers.

The red bread mold Neurospora [SCIENTIFIC AMERICAN, September] is an experimental organism used in the study of this problem. In a whole series of experiments in which mutated Neurospora strains were created by ultraviolet radiation that knocked out a single gene in each case, each missing gene resulted in the organism's inability to synthesize a specific foodstuff, indicating that the heredity-transmitting molecules are directly connected with the production of enzymes. In fact, it has recently been indicated that a strain of Neurospora lacking a particular gene actually lacks an enzyme which can be extracted from strains having a full complement of genes.

To proceed from Neurospora to man, there are certain human diseases that are due to the deficiency of single enzymes. Significantly, these diseases also are inherited according to strict Mendelian laws. The lack of a single enzyme in the metabolism of the amino-acid phenylalanine is sufficient to cause a form of mental defectiveness, while another missing link in the same system is responsible for albinism. Since each of these diseases can ultimately be traced to the hereditary defect of a single gene, and the agency in each case is a missing enzyme, circumstantial evidence argues strongly for the theory that each gene is associated with the making of a single enzyme.

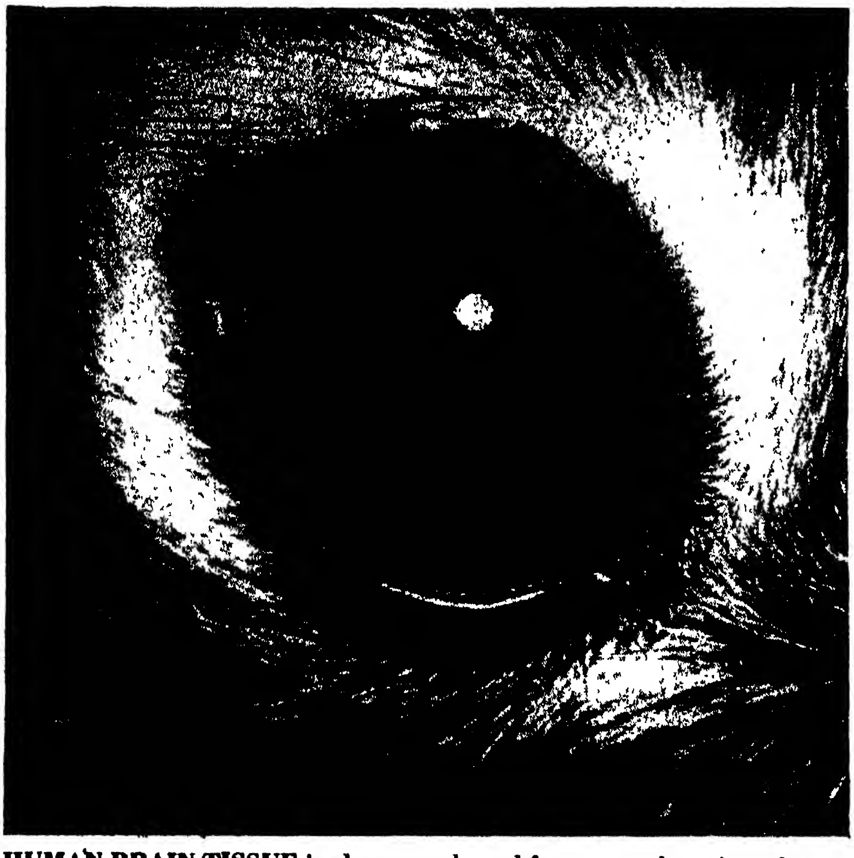
So enzymes bring us finally to the very core of the cell, and to the core of all biological problems. The solution of these problems depends more and more on our understanding of proteins, and particularly of enzymes, self-duplicating and otherwise.

John E. Pfeiffer was formerly science editor of Newsweek *and science director of the Columbia Broadcasting System.*



THEORY OF DRUGS that inhibit enzyme action is illustrated by the structural similarity of vitamins and the corresponding inhibitors. At top, for example, sulfanilimide is structurally similar to para-aminobenzoic acid.

HUMAN LUNG TISSUE grows under the cornea of a rabbit's eye. The tissue was originally transplanted from a human embryo. Cells became specialized later. Transplantability of embryonic tissue may relate it to cancer.



HUMAN BRAIN TISSUE is also transplanted from an embryo into the eye of a rabbit. Cells now have characteristic organization of brain tissue. They even exhibit some nerve activity when tested with electroencephalograph.

ON THE

THE problem of cancer is primarily a problem of behavior. A pathologist who examines tumor tissue under the microscope may observe significant details of form and structure, but he can never determine its malignancy from its appearance alone; only by its behavior in the living body can malignant tissue be unmistakably identified. Of two tumors with cells that look exactly alike, one may remain static or even disappear while the other inexorably spreads and kills the patient. Unfortunately many kinds and conditions of tissue which are not malignant bear a remarkable resemblance to cancer, and the pathologist often cannot distinguish between them. The diagnosis of cancer today does depend mainly on the analysis of cell morphology or appearance, but it is an imperfect guide. A judgment of the character of tissues from their appearance may indeed be as fallacious as an assessment of a man's qualities from his facial features.

We have been studying the behavior of living tissue in our laboratory by the device of transplanting it from one animal to another. The discovery many years ago that malignant tissue could be transplanted from its host to normal animals of the same species gave strong support to the idea that cancer is an independent, autonomous growth which can continue to grow even when it is removed from the conditions that originally produced and developed it. This concept in turn suggested the exciting possibility that a tumor might be transplanted from one species of animal to another; thus human cancer might be transferred to lower animals and experiments could be performed that would not be permissible in a human patient.

Many attempts at such transplantations were made; all failed. A study of these attempts suggested that it was not the concept but the methods used that were at fault. In our laboratory we had for some time been using the chamber of the eye behind the cornea in animals as a transplanting site, and the physiological conditions in this organ suggested that it might be a peculiarly favorable site for human cancer transplants. Our experiments proved successful; we found that we could grow many types of human can-

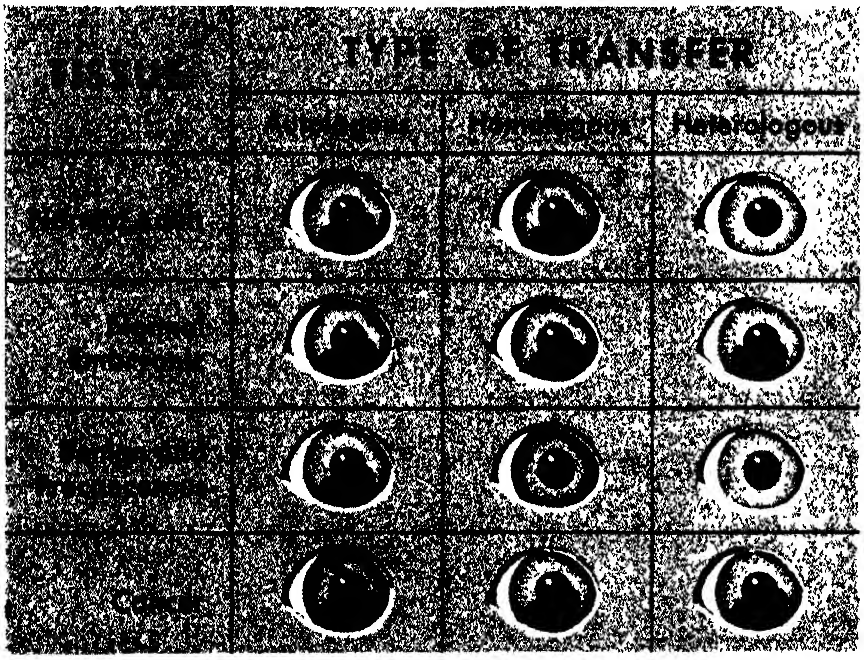
DEVELOPMENT OF CANCER

Transplanting tissue from one species to the eye of another yields a new insight into the nature of the malignant process

by Harry S. N. Greene

cer in the eyes of guinea pigs and rabbits.

Was cancer tissue unique in this property, or could other types of tissue also be transplanted from one species to another? Here was a means of comparing the behavior of cancer tissue with that of other kinds. We tested and compared four different types: normal adult tissue, normal embryonic tissue, benign and precancerous tumor tissue, and full-fledged cancer tissue. For each tissue three kinds of transplantation were tried: autologous (from one site to another in the same individual); homologous (from one animal to another of the same species); and heterologous (to an animal of a different species). The results are shown in the chart above.



SUCCESS OF TRANSPLANTING tissue in the eye of an experimental animal depends on source of tissue and type of transfer. Here eyes containing tissue show successful transfer; eyes without tissue, unsuccessful transfer.

Thus it was found that all four types of tissue could be transplanted back in the same animal; all but benign tumor and precancerous tissue could be transplanted to normal, unrelated animals of the same species; only embryonic and cancer tissue could successfully be transferred to an alien species. This finding at once suggested a biological test for human cancer: If a specimen of the suspected tissue can be transplanted to the eye of a guinea pig, it is either embryonic tissue or cancer, and even surgeons can easily distinguish between the two.

When this test was made, the significant fact developed that results of our biological test often disagreed with the diagnosis of the same tissue based on its microscopic examination. An illustrative case follows: A middle-aged man entered the hospital with a large tumor in his chest. X-ray examination showed no evidence that the tumor had metastasized (spread to other sites) and the growth was removed by surgery. On the basis of morphological examination of the tissue, it was diagnosed as a fibrosarcoma (cancer of the connective tissue). But transplants of the tissue in guinea pigs' eyes failed to grow, which indicated that by our biological definition the lesion was not full-fledged cancer. Six months later the patient returned with a recurrence of the tumor at the same site. There was still no evidence of metastasis; the appearance of the tissue had not changed; transplants still failed. An attempt was again made to remove all the tumor tissue, but again the operation was apparently inadequate, for eight months later the patient had another recurrence of the tumor. This time X-ray studies showed that the growth had metastasized to the lungs. The morphological appearance of the tissue had not changed, but the biological test of its behavior produced sharply different results: transplants of the tissue now grew in all of the guinea pigs used.

This is not an isolated case; similar tests of tissue specimens from other cancer patients show an identical course of development. It is significant that all tumors which possess the ability to invade and metastasize to other tissues in the body can be transplanted to animals of alien species, while many lesions judged to be cancerous on purely morphological grounds cannot be transplanted. Moreover, patients with disorders diagnosed as cancer by morphologists not infrequently make a complete recovery, whereas a diagnosis of cancer based on the behavior of the tissue is invariably followed, in spite of all attempts at treatment, by the death of the patient.

THESE disagreements in diagnosis have led to considerable controversy among pathologists. The bone of contention is, of course, the definition of cancer. The morphologist defines cancer as a group of cells with certain specific characteristics of structure and arrangement; the biologist, on the other hand, considers that the distinguishing feature of cancer is its ability to invade and metastasize.

The biological view suggests a fundamentally new concept of the entire cancer process. It has long been supposed that cancer is the result of a sudden transformation of normal cells into malignant ones. Some unknown factor or set of factors, according to this view, changes the character of previously healthy tissue so that it grows rapidly and malignantly. The new evidence on the behavior of various types of tissue, however, strongly indicates that cancer is not the result of a sudden transformation, but is the final product of a developmental process. The tumor goes

through evolutionary stages during which it does not change in appearance, but does change profoundly in its biological behavior. In the case which I have described, the tumor tissue, although it had the morphological appearance of cancer, did not at first behave like cancer tissue in the patient. Moreover, it was not transplantable to another species of animal. As the tumor developed, however, it acquired the ability to invade and metastasize and the attainment of these properties was associated with the ability to grow in an alien species. This change was demonstrated only in its behavior; it could not be detected by any alteration in the appearance of the cells.

What caused the change in behavior? Some light on this question may be obtained from a study of the reactions of tissues to homologous transplants from one animal to an unrelated animal of the same species. As we have seen, precancerous tumor tissue, *i.e.*, tissue in the process of development to cancer, cannot be transplanted to a normal animal of the same species, although all other types of tissue can be. If, however, the second animal is not normal, but itself has a spontaneous tumor of the same nature as the first animal's, homologous transplants of tumor tissue can easily be made to it. Evidently, then, tumor growth and development are dependent on certain specific biological factors which are present in the original animal and in other tumor-bearing animals, but which are not supplied by normal animals. In its developing stages, the tumor requires these factors to survive and mature. When its development is completed, however, the tumor becomes an independent growth that can thrive in the absence of such factors, and transplants will grow in normal animals.

In the case of the patient with a chest tumor, the tumor appears to have been in a dependent phase during the period when the first two operations were performed. If the tumor tissue had been completely removed at that stage, the patient would have survived and the case would have been recorded as a "cancer cure," despite the fact that from a biological point of view the tumor was not a cancer at all. It is not improbable that all instances of so-called cancer cures are of this kind. Actually small fragments of tumor were missed in both operations, and they eventually became autonomous, metastasized, and killed the patient.

The conception of a dependent phase in the development of cancer suggests several fields of inquiry. The most obvious question is: What are the factors on which the biological development of a tumor depends? A detailed search for constitutional differences between the normal animal and the tumor-bearing animal is a logical approach to the problem. Such an investigation has been undertaken in cancers of the uterus and mammary glands in rabbits. Here the problem is relatively simple, for the affected animals show obvious evidence of an endocrine disorder involving the estrogenic hormone. To test the influence of this factor, an endocrine disturbance was artificially produced in normal animals, and dependent (precancerous) tumor tissue was then transplanted into their eyes. The transplants were successful; transplants attempted in untreated control animals, on the other hand, did not succeed. The experiment demonstrated that the endocrine disorder was an essential factor in development of this type of tumor.

Tumors of the breast and uterus are special cases, for endocrine disorders are not associated with all tumors. Yet constitutional disturbances of a different order do accompany other tumors. It seems highly probable that, in a similar fashion, they constitute the factors essential for the tumor's growth and development. An investigation of these factors is of the utmost importance for the rational treatment of tumor patients; if the factors can be discovered and eliminated, the development of tumors to cancer may be stopped. This does not apply, of course, to the fully evolved cancer, for in such cases the growth has attained autonomy and is completely independent of the factors concerned in development.

For the present, heterologous transplantation provides a reliable test for cancer. If the specimen of tumor tissue can be transplanted successfully to a normal animal which contributes none of the factors known to be involved in tumor development, it means that the tissue has attained independence and is a true, autonomous cancer. This test gives information that cannot be obtained through the microscope, and, further, is a considerable aid to the microscope in the classification of cancer.

NOT infrequently the first sign of cancer in an individual is the appearance of a metastasis. This may occur as an enlarged lymph node in the immediate vicinity of the primary growth, or it may be far distant from the involved organ. In such cases, the surgeon removes a portion of the metastatic growth and sends it to a surgical pathologist, who attempts by a microscopic study of its appearance to determine in what organ or tissue the growth originated. If the metastasis retains the characteristic architecture of the differentiated or specialized cells in the original organ, the task is relatively simple. But if, as frequently happens, the cells are poorly differentiated and disorganized, and the picture is complicated by the death of cells or obscured by reactive processes, microscopic study is of little help in locating the primary site. Fortunately when such cancers are transplanted to normal lower animals they develop a higher degree of cellular differentiation and structural organization than they possessed in the patient; thus it becomes possible to classify the cancer and identify its place of origin more precisely than from a study of the original specimen.

The following cases illustrate this use of heterologous transplantation:

A 45-year-old woman appeared for examination with a greatly enlarged lymph node in the groin. The node was removed and on microscopic examination showed a preponderance of dead cells, with scattered cancer cells of nondescript appearance. There was nothing to indicate the proper classification or the site of the primary tumor. Fragments of the tissue were transplanted to guinea pigs; after 20 days the animals were killed and specimens of the growing transplants were examined under the microscope. The cells now showed such well-marked characteristics of structure and organization that the growth was readily diagnosed as malignant melanoma (cancer arising in a nevus, or birthmark). When questioned, the patient then recalled that she had had a birthmark removed from her foot several years before; the tissue had not been examined, however, and both the doctor and the patient had assumed that it was entirely benign.

The second case is that of a young woman of 24 who had a growth removed from her upper backbone. The growth was diagnosed as hemangioblastoma (tumor of blood vessels); the microscopic picture showed the classical signs of such a tumor. The growth was not completely removed by the operation; three years later the patient re-entered the hospital with a recurrence of the tumor. A second operation was performed. The tumor tissue had become more disorganized in structure, but its appearance was still consistent with hemangioblastoma and it was again so diagnosed. When grafts of the tissue were made to guinea pigs' eyes, however, the transplants in 12 days developed a well-organized growth of cells which showed the characteristic signs not of a tumor of blood vessels but of a cancer of cartilage. The surgeon in the case was understandably very skeptical of this new diagnosis. But when the patient died, about a year later, microscopic examination of the patient's metastasis at autopsy confirmed the guinea pigs' veracity.

The use of heterologous transplantation as an aid in cancer diagnosis is a simple procedure. The technique requires only an elementary knowledge of surgery. Interpretation of the results is almost foolproof. Although the grafting test itself fails to distinguish between cancer and embryonic tissue, which, as was noted at the beginning of this article, can be transplanted to an alien species just as cancer can, this fact does not invalidate the test, for the differences between an embryo and a cancer are fully apparent on gross examination.

On the other hand, the similarity in the reactions of cancer and embryonic tissue is itself of great theoretical interest. The

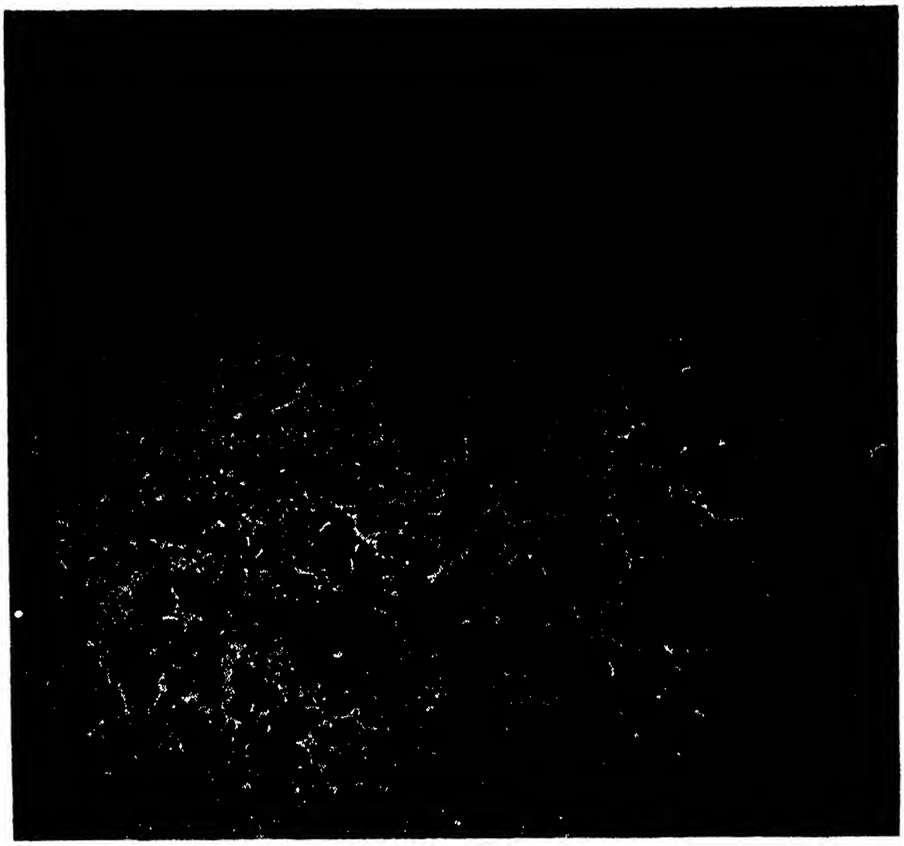
resemblance between the two types of tissue is not limited to transplantation reactions, but is also observed in biochemistry, immunology and morphology. Indeed, the only major difference between the two tissues is that, in the primary host and in experimental animals, embryonic tissue progresses to differentiation or specialization of function, while cancer does not. Embryonic tissue may be transplanted from any organ of the fetus. And all transplants of this tissue, whether homologous or heterologous, undergo differentiation into the organs that would have evolved had the tissue remained in its original site. Thus mammary tissue, when transplanted from any animal to a guinea pig's eye, develops into small mammary glands and can actually be seen to produce milk. The cells of cancer tissue, in contrast, simply reproduce themselves and show no changes indicating specialization.

These facts suggest that the step from embryonic tissue to cancer is relatively short, and that this step is probably concerned with the process of differentiation. Accordingly, one of our endeavors has been to inhibit or modify the differentiation of embryonic tissue transplants with the hope of thus producing a cancer. Various methods have been tried; to date, success has been attained only through use of the well-known cancer-producing chemical, methylcholanthrene.

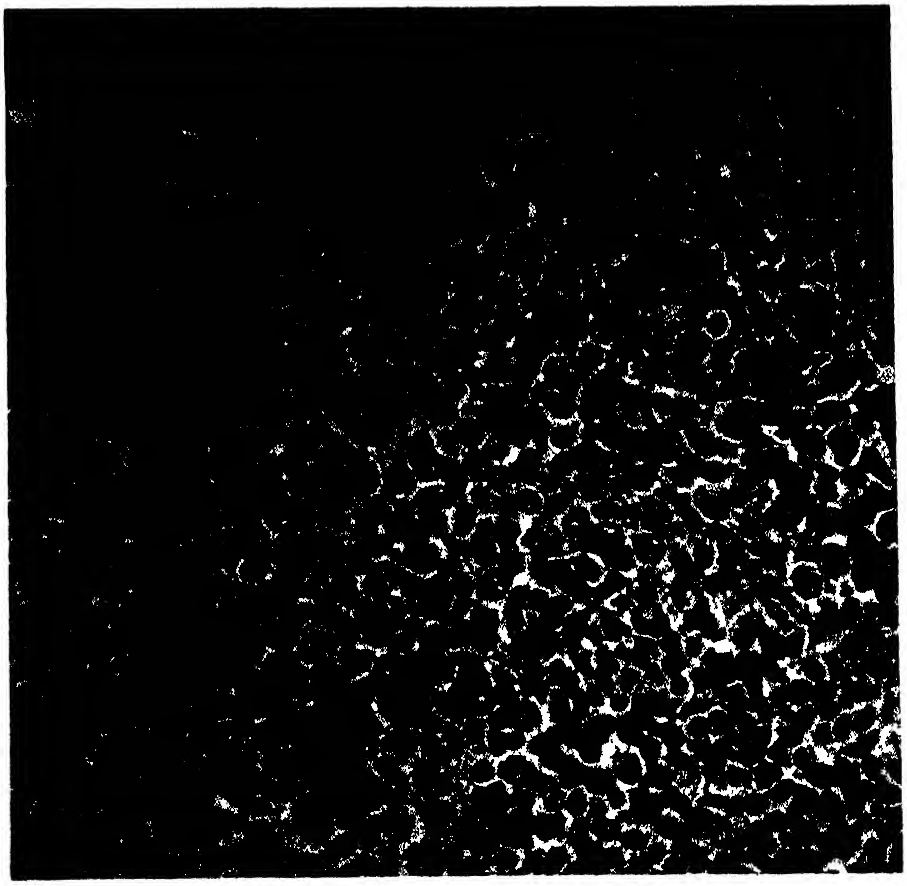
The technique is easily explained. A minute crystal of methylcholanthrene is added to a specimen of embryonic tissue and the tissue is then transplanted to an adult animal. In from 30 to 40 days, a cancer develops in the transplant. This is a significantly short period, for ordinarily it takes from four to six months to produce cancer in the same tissue of an adult animal. Moreover, all attempts to produce cancer in certain adult organs by means of this chemical have proved unsuccessful, whereas cancer is readily induced in their embryonic counterparts. Any organ—the eye, the abdominal cavity, the kidney, a lung, the deeper layers of the skin—can be used as a transplantation site for treated embryonic tissue without changing the result.

The close relationship between cancer and embryonic tissue opens a promising field for further investigation, and many additional experiments are under way or planned. The experiments already performed appear to establish pretty definitely that cancer is not a sudden transformation of normal cells, but on the contrary represents the final step in a developmental process. And the constitutional abnormalities present in tumor-bearing animals suggest that cancer is not simply a local tissue disease, but rather a local manifestation of a generalized disorder.

Harry S. N. Greene is professor of pathology at the Yale University School of Medicine.



CANCER TISSUE mounted on a microscope slide is from a lymph node of 45-year-old woman mentioned in text of this article. Nondescript organization of cells made it impossible for pathologists to identify original tumor.



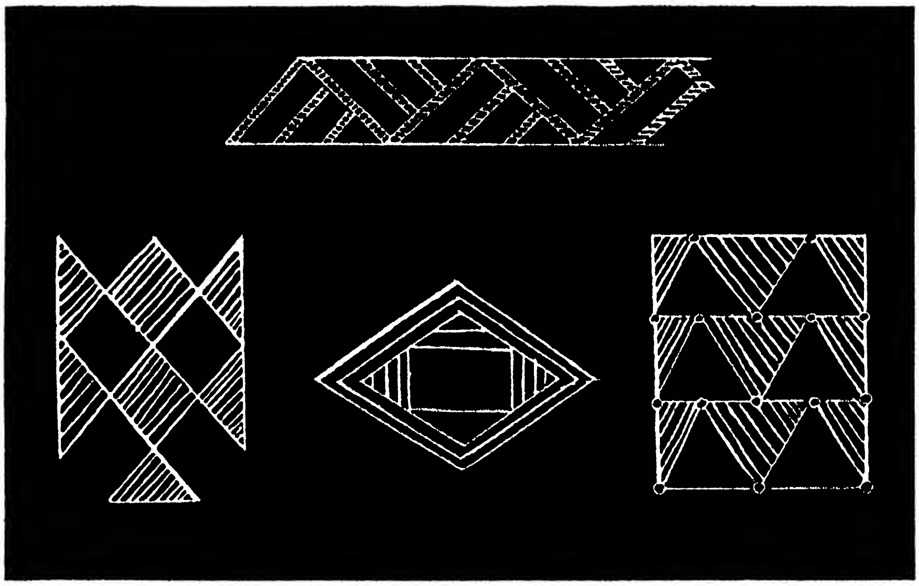
SAME TISSUE, after transplantation in the eye of a guinea pig, developed recognizable cell organization. From this slide pathologists were able to identify original tumor as a melanoma, or a cancer arising from a birthmark.

STONE AGE MATHEMATICS

The earliest comprehension of number and geometry appears to go back farther than the time of the Egyptians and Babylonians

by Dirk J. Struik

WHEN did mankind begin to use mathematics? It has long been customary to attribute the invention of this science to the Egyptians and Babylonians of the fourth or perhaps fifth millennium B.C. But if we assume that mathematics was born when men began to have some understanding of numerical and geometrical relations, then mathematics is much older than those ancient peoples. Its history goes back to the primitive races of neolithic times, and even the Old Stone Age. Indeed, there is some question whether we should stop there. Charles Darwin in his *Descent of Man* was sure that some of the prerequisites for mathematical reasoning, such as memory and imagination, exist among the higher animals. We may take it that man in his early stages borrowed some mathematical notions from his animal ancestors.



GEOMETRICAL PATTERNS, generally drawn on pottery, are neolithic expressions of interest in mathematics. Those at left and right show attempt to develop triangular numbers, later important in Pythagorean mathematics.

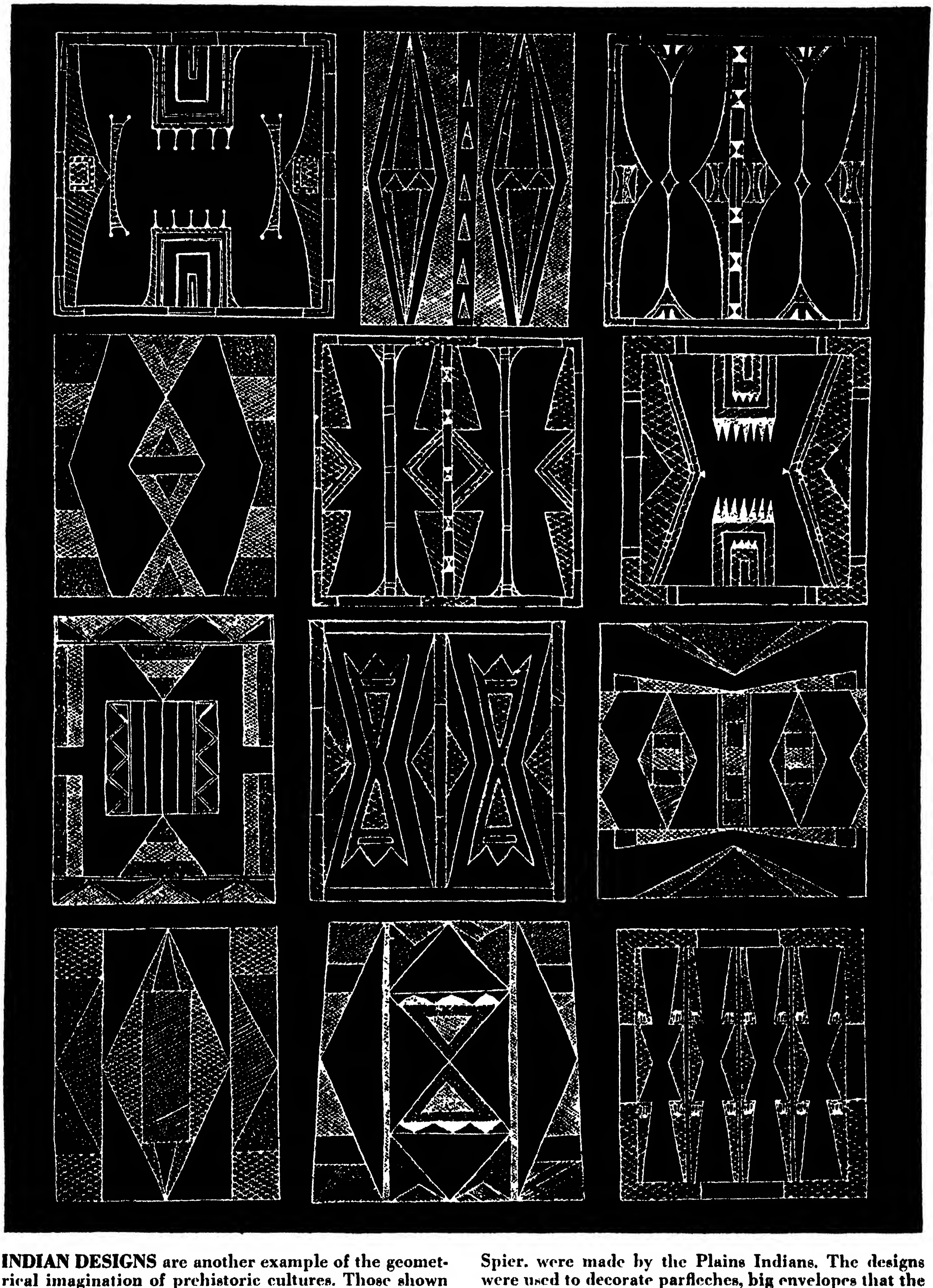
Even in his primitive stages, however, this man is already a mathematical prodigy compared to the higher apes. He begins to develop an articulated language, in which hardly any generalizations or abstractions occur, each expression being associated with some object or set of objects. He can express at least the difference between a single specific object and many such objects. Some conscious knowledge of order, size and form begins to appear. And above all, he introduces a new element into the evolution of living beings, an element which endows him with the potentiality for further development.

This new element can be defined as the process of labor. By means of labor man enters into a new form of active and conscious contest with nature; he begins to change nature and thereby changes himself. He invents tools. His labor slowly develops into a social activity. Very early in this process, certainly by the Old Stone Age some hundreds of thousands of years ago, he begins to acquire his first conscious understanding of numerical and spatial relations.

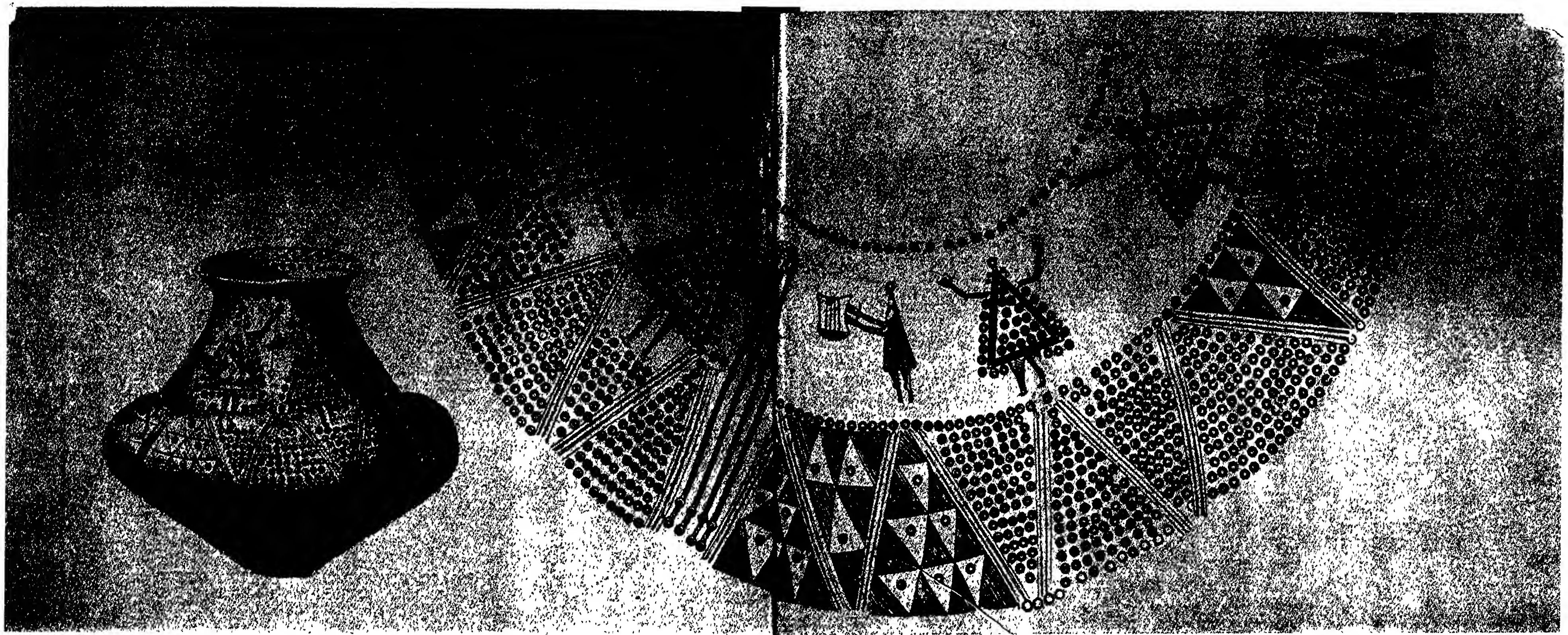
We can get some idea of the nature of this early paleolithic culture from studies by modern anthropologists of primitive tribes in Australia and Polynesia. These tribes were primitive hunters and fishermen; they had no agriculture and only the simplest tools; they lacked even the bow and arrow, which some tribes of the Old Stone Age are known to have possessed. But the Australian and Polynesian tribes already had the beginnings of a number system. Their languages had words for "one" and "two"; many of them counted up to 3 or 4, expressed as the sum of 1 plus 2 and 2 plus 2. Their language rarely went beyond the number 4. A few, however, had a special term for 3, and this step apparently represents a considerable advance beyond the primitive method of pairing. The early development of numbers is illustrated by the language of the Kamilaroi tribes in Australia: their word for 1 is *mal;* for 2, *bulan;* for 3, *guliba;* for 4, *bulan bulan* (2 plus 2); for 5, *bula guliba* (2 plus 3); for 6, *guliba guliba* (3 plus 3).

The earliest number concepts among primitive tribes are qualitative rather than quantitative. Just as we speak of one book as "a" book, primitive peoples think in descriptive terms rather than in numerical abstractions in designating two or even more objects. This frame of reference, which is reflected in their grammar, has come down in some modern languages; for example, in Greek and Celtic there are special terms for two objects, and German still uses *ein* both for "one" and for the article "a" (*ein Baum*) and declines the word as if it were an adjective (*eines Baumes*).

When primitive peoples made the transition from being mere food gatherers to becoming food producers, they progressed considerably in the understanding of numerical values and space relations. This great event in the emancipation of man, which marked the transition from the Old Stone Age (Paleolithicum) to the New Stone Age (Neolithicum), occurred independently in various parts of the earth at different times, beginning perhaps 10,000 years ago. As neolithic man settled down to primitive farming and semi-permanent dwellings and villages, he developed pottery, carpentry, weaving, baking, brewing; and the smelting of copper and bronze. Invention followed invention: the potter's wheel, the wagon wheel, the hammer, the hoe, tents, huts, rafts, boats. These inventions did not always spread widely; the American Indian, for instance, did not know the wagon



INDIAN DESIGNS are another example of the geometrical imagination of prehistoric cultures. Those shown on this page, recorded by the anthropologist Leslie Spier, were made by the Plains Indians. The designs were used to decorate parfleches, big envelopes that the Indians made by folding rectangular pieces of rawhide.



POTTERY DESIGN of an early culture in western Hungary shows a certain degree of geometrical sophistication. At left is an urn; at right is a two-dimensional representation of its decoration. Of principal interest to the mathematician are the triangular designs at the bottom of the decoration. Such designs often led to the development of geometrical ideas.

wheel until the coming of the white man. Nevertheless, in comparison with paleolithic times the tempo of technical improvement was enormously accelerated. A spur to the development of arithmetic was the rise of trading among neolithic settlements. Number systems had to be developed to keep track of catches of fish, the size of the herds and harvests, the requirements of barter and the beginnings of a calendar.

The first step was to bundle numbers into larger units. This is the principle of the old innkeeper's tally stick which everyone adopts who has to count cons or votes: he takes groups together and considers each group as a new unit. One would naturally assume that man began to count on his fingers—an assumption which seems to be supported by the now almost universal decimal system. Actually counting by 5s and 10s did not appear until a relatively advanced state of civilization. The most primitive peoples bundled things in pairs, counting them in groups of 2, 4 and 6. An occasional variation was the ternary number system (groups of 3), which was used by a number of American tribes.

HOW difficult it is for primitive man to progress to counting on his fingers is illustrated in an account of the Damara, a Bantu tribe of southwest Africa, by the British anthropologist Francis Galton: "When inquiries are made about how many days' journey off a place may be, their ignorance of all numerical ideas is very annoying. In practice, whatever they may possess in their language, they certainly use no numeral greater than three. When they wish to express four, they take to their fingers, which are to them as formidable instruments of calculation as a slide rule to an English schoolboy. They puzzle much after five, because no spare hand remains to grasp and secure the fingers that are required for units. Yet they seldom lose oxen: the way in which they discover the loss of one is not by the number of the herd being diminished, but by the absence of a face they knew."

The quinary (counting by 5s) and decimal systems are biologically so inevitable, however, that they eventually appear among primitive peoples in many parts of the world. Of 307 number systems among primitive American tribes which were investigated by the Stanford University mathematician Walter C. Eells, 146 were decimal, 106 quinary and quinary decimal, 81 binary (counting by 2s), 35 vigesimal (by 20s) and quinary vigesimal, 15 quaternary (by 4s), three ternary and one octonary (by 8s). The vigesimal system occurs in its most characteristic form among the Mexicans, the Mayas and the Eskimos. On the continent of Europe it is typical for the Celtic languages, and traces of it are left in French: 80 is *quatre-vingts*.

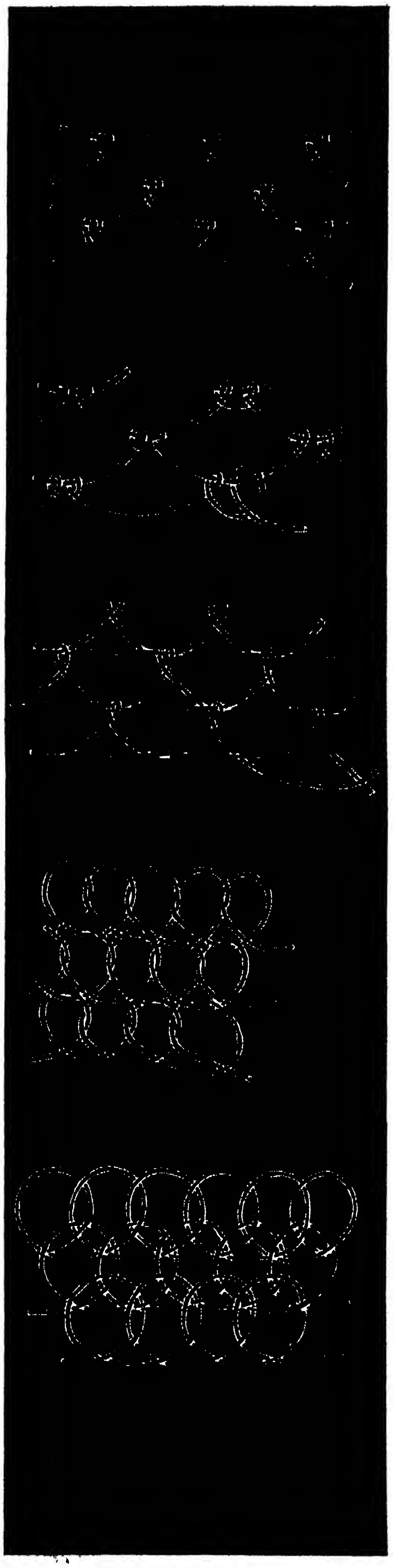
In the ancient Greek, the word *pempazein* (literally counting by 5s) stands for counting in general. It seems likely that as primitive peoples developed the need for larger numbers they progressed from counting with one hand to using both hands and then in some cases using both hands and feet. From this method of bundling to the introduction of special symbols for 5, 10, 20 and so on was a natural next step. We find exactly such symbols in use at the beginning of written history—the so-called dawn of civilization.

Once the principle of a number system is grasped there is little to prevent the extension of the system to large numbers. This may happen, for instance, among peoples in possession of large herds, or wherever a well-developed agriculture requires the beginning of a calendar system. The Sioux, Iroquois, Muskoghean and some Algonquin Indians were reported capable of counting in the hundreds of thousands, and occasionally they had words for even higher numbers. Eells remarks that they had developed this ability even though before they came into contact with European civilization these Indians had little occasion to use numbers beyond 1,000. Primitive peoples loved very large numbers, a fondness which was perhaps stimulated by the desire to exaggerate the extent of herds or the number of enemies slain. The ancient Hindus occasionally dealt with no less than 18 powers of 10. In true primitive fashion, they had a special term for each power. Their prowess in counting has occasionally been presented as evidence of the superiority of ancient Hindu mathematics, but in view of the counting achievements of other peoples their mathematical understanding cannot be considered unique.

An important step in the development of arithmetic is the keeping of numerical records. The primitive methods of doing this all used the bundling or grouping system: pebbles or shells arranged in heaps of 5, knots on a string, nails pressed into a board. With the invention of a special token for 5 and 10 a real arithmetic began. Addition started when numbers were written as sums of other numbers greater than 1; in other words, when 4 was expressed, not only as 1 plus 1 plus 1 plus 1, but also as 2 plus 2 or as 3 plus 1. From this it was but a step to subtraction, the number 14 for example, being expressed as 15 minus 1 and 30 as 40 minus 10. The beginning of multiplication came when 20 was expressed as 2 times 10 instead of 10 plus 10. This simple doubling operation, a middle road between addition and multiplication, was used for thousands of years; it was especially prominent in Egyptian mathematics. The use of fractions appears to be a fairly sophisticated development, for it was rare among primitive tribes. Indeed our words for 1/2, such as half, semi, demi, have no relation to the number 2, which indicates that this concept was not consciously introduced as a fraction.

EQUIPPED with these improvements in counting ability, primitive peoples began to develop a livelier interest in measuring things. The standards for length are usually taken from parts of the body: the finger, the foot, the thumb, the hand, the forearm and so on. Volume is measured by shells or by buckets of fairly standardized size. When houses are built, as among the agricultural Indians or the pole house dwellers of prehistoric Central Europe, rules for building along straight lines and at right angles are laid down.

On the coast of British Columbia, for example, the Indians use as the principal measures the width of a finger, a long span (from thumb to tip of fourth finger), a short span (from thumb to tip of first finger) and a cubit (from elbow to tip of second finger). The Hupa of southern California measured their dentalium shells by the length of the finger joints and by



NETTING made without knots by a number of primitive tribes, notably those of South Pacific, requires high order of geometrical imagination.

marks tattooed on the forearm according to certain accepted standards. The Kwakiutl, an Indian tribe of Vancouver Island in British Columbia, had a well-developed procedure for laying out the lines for a square house. From a point which was to be the middle of the front line of the house, they stretched a rope to the middle of the rear line. After staking these two points, they halved the rope and stretched one half to the right and the other to the left of the front stake. Then, using another rope to measure the distance from the rear stake to the ends of the front rope, they adjusted the latter until the distances between the rear stake and the two front corners were equal. In this way the front line was placed exactly at right angles to the middle line. The rear corners were determined in the same way.

Neolithic man showed an early interest in geometrical patterns. This was the result of the growth of handicrafts: the turning, baking and coloring of pottery, the plaiting of rushes, the weaving of baskets and textiles, and later the working of metals. Neolithic decoration abounds in examples of congruence and of various forms of symmetry. Numerical relations may enter and blend with plane and spatial patterns; certain prehistoric ornaments show triangular numbers, others "sacred" numbers.

ASTONISHING examples of very complicated geometrical figures in a very primitive society were discovered by the British anthropologist A. B. Deacon among tribes in the New Hebrides. A few of these drawings are shown on the opposite page. They were apparently once connected with religious ceremonials, but they are now drawn in the sand, as a pastime with no deep symbolism, by tribesmen gathered for amusement.

Some authorities hold that the determining factor in the growth of mathematics was its magical aspect. There is no reason, however, to assume that rational mathematics grew out of mysticism, as some contend. The social roots of mathematics may become obscured in modern times, but they lie clear in earlier ages. There are, to be sure, plenty of indications that mathematics has always been associated with magic; remnants still exist in the belief in lucky and unlucky numbers and in the pseudo-science of numerology.

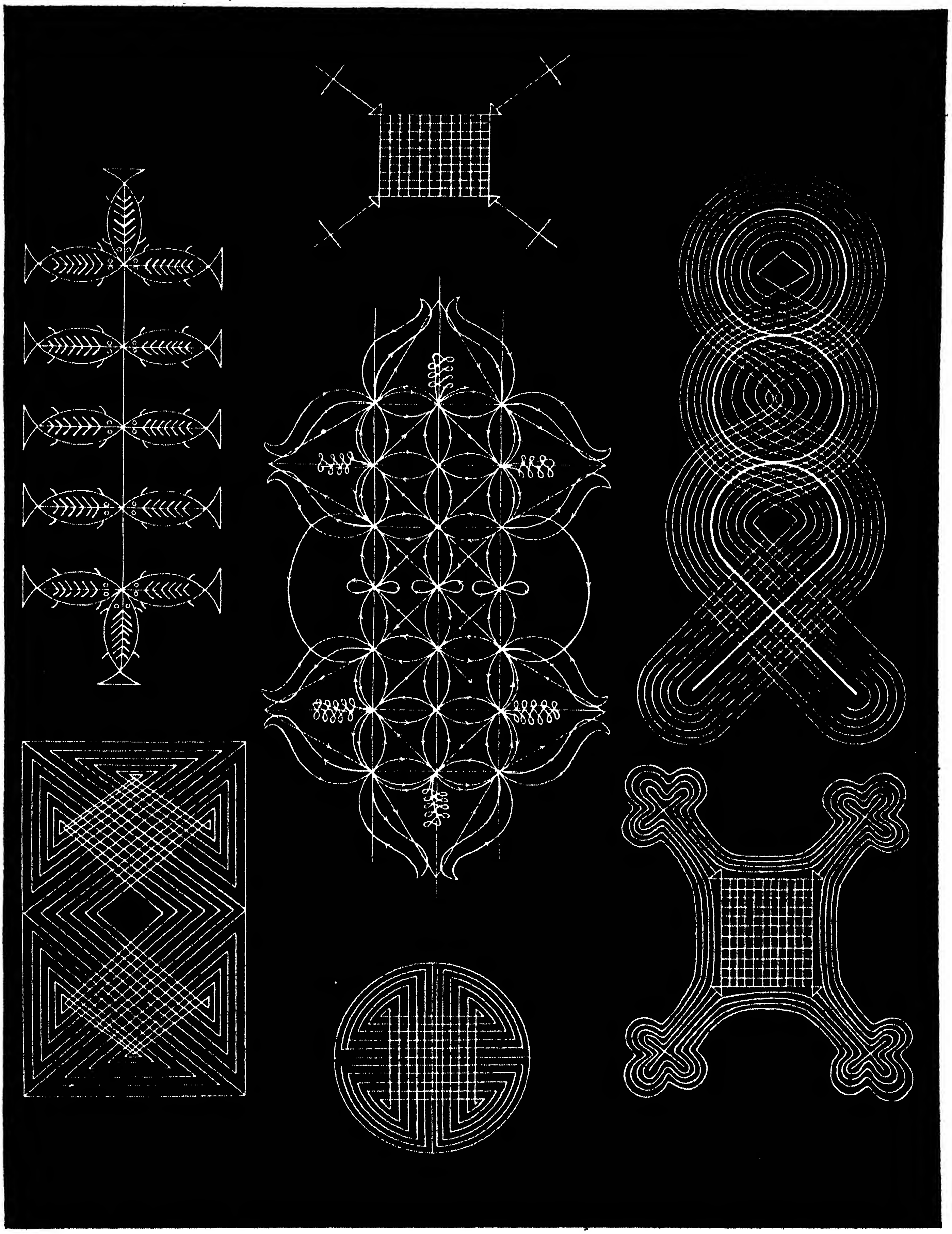
The number 4 was given mystical powers by many primitive peoples. This superstition found expression in cults which attributed a mystical significance to the four quarters of the compass and in the widespread cults of the swastika and other cruciform symbols. Other mystical numbers were 6, 7 and 13. The German anthropologist Leo Frobenius reported on the connection of certain numbers, such as 2 and 3, with sex relations. Many of the geometrical patterns in primitive pottery, weaving and basketmaking probably contained some magical meaning.

The development of mathematics was most strongly influenced, however, by natural science, especially astronomy. Even among very primitive tribes there was some knowledge of the sun, moon and stars, and with the expansion of agriculture this knowledge deepened. Almost universally primitive peoples adopted a lunar calendar, for the lunar period of almost a month is a practical unit for farming. Thus most of the phases of the moon are named for the changing aspects of vegetation or the ripening of wild fruits; other agricultural names were given to the phases of the position of heavenly bodies, the rising of the Pleiades, the solstices of winter and summer. The Micronesians used the constellations as guides in navigation. The Egyptians, Indians and Chinese all ascribed some knowledge of astronomy to their prehistoric periods.

The mathematical interests of neolithic men were not all of what we now consider an elementary nature. Many aspects of their geometrical patterns were so complex that they have found an adequate mathematical analysis only in modern group theory and in topology. The evidence shows that the historical growth of mathematics did not follow the sequence used in modern instruction on the subject. Some of the oldest mathematical topics belong to what we consider modern science, while some of our "elementary" mathematics, such as graphical representation, developed only in relatively modern times. Of course primitive peoples made no abstract or systematic study of their geometrical patterns and knots, to say nothing of group theory or topology. What did exist was a widespread search for new and varied forms. Their gropings are perhaps comparable to the mode of work of painters, architects and sculptors in modern times; modern science has not succeeded even yet in analyzing all the mathematical elements in art.

We can sum up the evidence by saying that the beginning of arithmetic and geometry is found in the Stone Age civilizations of hunters and early farmers. It was based on the necessities of their social and economic life, was influenced by magic and religion, and was perhaps already inspired by a sense of the sheer charm of mathematical order. Certain rudimentary beginnings of a more abstract approach can be discovered in primitive peoples' systems of numbering, addition, multiplication and measurement, in the formation of geometrical symmetries of varied character, and in the beginnings of a calendar.

Dirk J. Struik, author of the recent book Yankee Science in the Making, *is professor of mathematics at the Massachusetts Institute of Technology.*



GEOMETRICAL FIGURES drawn by the natives of the New Hebrides are examples of unusually complicated designs made by the people of a very primitive culture. Originally these figures were worked out for religious ceremonies, but now they are drawn by the New Hebrideans mainly for amusement. The mathematical analysis of many figures such as these requires a knowledge of modern mathematics such as group theory and topology.

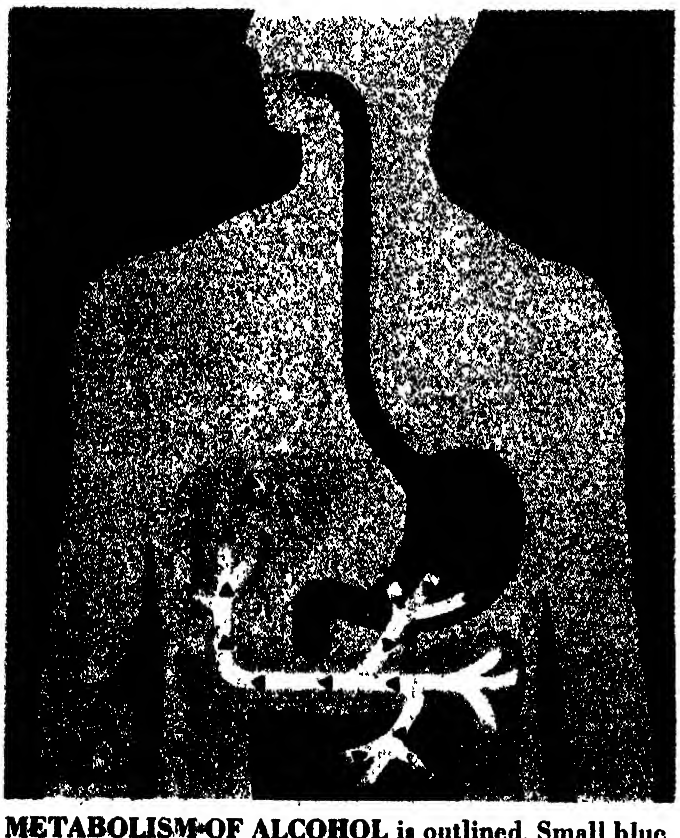
ALCOHOLICS AND METABOLISM

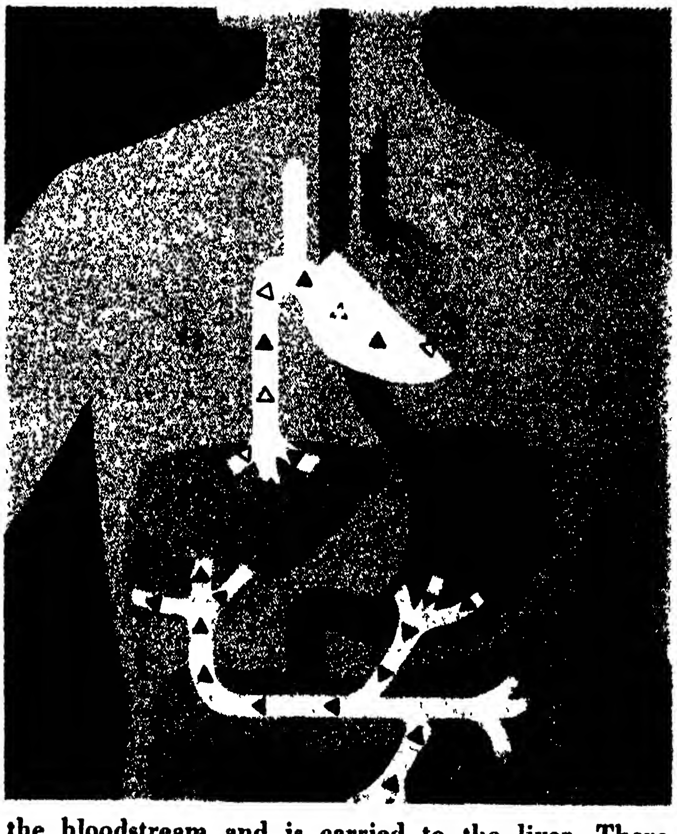
Individuality, points out the author, has a basis in biochemistry. The study of such variations may help in determining what creates compulsive drinkers

by Roger J. Williams

EACH of us is born with a certain color of eyes and of skin, a certain ultimate limit of body size and certain facial features that stamp him as the child of his forebears—and also as a unique individual. The genes that control our inheritance are capable of so many different combinations that no two persons are exactly alike. This uniqueness extends throughout our whole morphology, from the gross and microscopic structure of each endocrine gland, each sense organ and each internal organ to the microscopic texture of our hair and the tiny ridges that cause our fingers, toes, hands and feet to yield distinctive prints.

But inheritance and distinctiveness do not stop there. Recent studies in genetics have shown that our genes control not only our structure but our physiological pattern. Every human being inherits from his forebears the intricate mechanisms which go to make up his entire metabolic machinery or, more specifically, the potentiality for producing the extremely numerous enzymes and enzyme systems about which biochemists are learning more each month and each year. George W. Beadle and his co-workers at the California Institute of Technology, using the technique of knocking out by X-rays the individual genes in the spores of the relatively simple organism *Neurospora*, have established in several cases a one-to-one relationship between genes and enzymes. It becomes inescapable that





METABOLISM OF ALCOHOL is outlined. Small blue triangles in first drawing represent alcohol taken into the stomach and intestines. From them it passes into the bloodstream and is carried to the liver. There alcohol is broken down into acetic acid, represented by open triangles. The broken triangles represent acetic acid

wherever there is a difference in inheritance, there is likewise a difference in the enzymes. And of course, a difference in enzymes means a variation in the course of the chemical reactions associated with metabolism.

These facts suggest that disorders of metabolism may be hereditary, and indeed we know of a few in which the connection between the genes and the disorder has been proved beyond any doubt. This article is concerned with the specific problem of alcoholism, or compulsive drinking. Is alcoholism the result of a peculiar metabolism? Is the tendency toward a craving for alcohol inherited? There is considerable evidence to suggest that it is.

To the layman, metabolism often represents simply the number of calories an individual consumes per day. Actually the term embraces a million chemical processes, more or less, which forerun and accompany the conversion of the chemical energy of food into the energy used by the body and that liberated as heat.

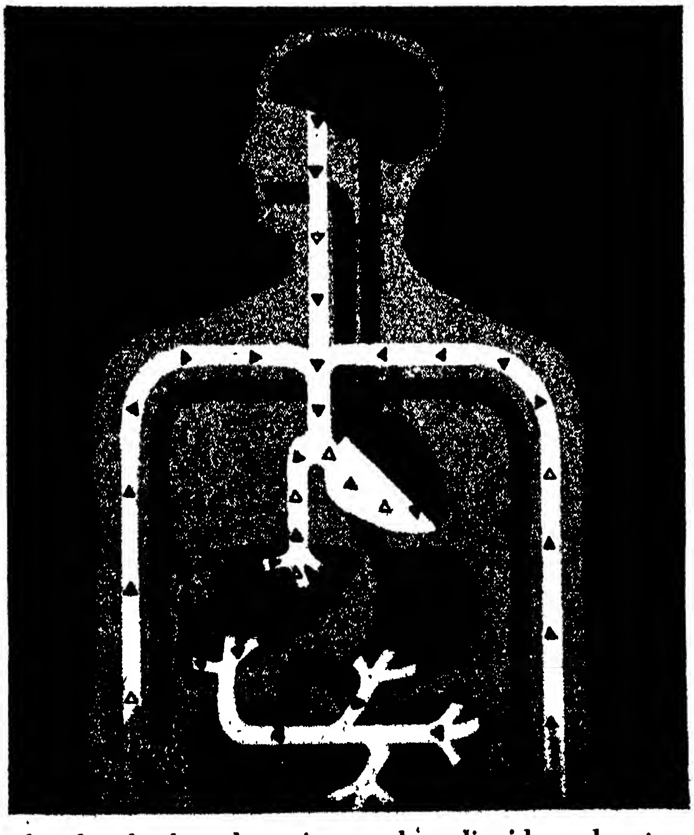
The general course of metabolism is the same in all human beings, but this does not mean that the process is identical in all. From a general point of view, indeed, the metabolism of men is much like that of rats. The same types of food are utilized and the same major end products are formed. When we compare the details of rat metabolism closely, however, we recognize certain marked differences. It is quite easy to concoct an excellent diet for rats upon which human beings will surely die. All that is required is to leave out one of the vitamins—ascorbic acid. This lack does not affect the rats, but it will kill human beings.

It is well known that individual human beings differ as to the amount of fat they can tolerate in their food, the amount of salt they require, and in their tendency toward obesity or its opposite. Furthermore, the ability of animals, notably dogs, to distinguish people by their odors, can be based only upon the fact that each individual produces his distinctive blend of metabolic products.

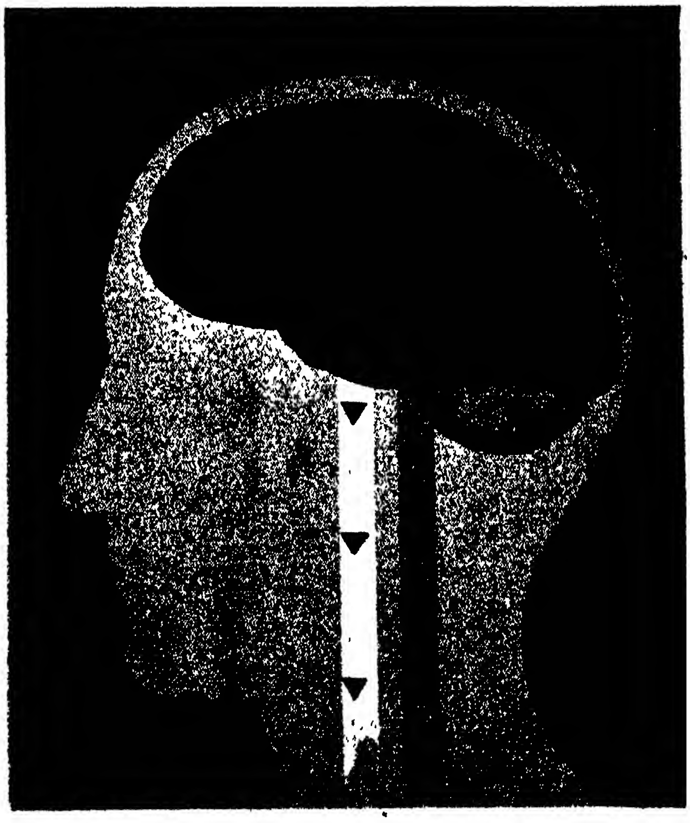
If the metabolism of individual people is distinctive, then there must be differences in the chemical processes taking place within them. Decades ago it was discovered that certain people exhibited, for some reason then unknown, metabolic peculiarities which were manifested by the presence of unusual chemicals in the urine. These conditions were not accompanied by disease; they were found to be inherited and were classified as "inborn errors" of metabolism.

Investigations being carried on currently at the University of Texas indicate that inborn differences (the term "error" is unfortunate) are commonplace rather than rare, and that individuals taken at random exhibit distinctive metabolic traits which become evident as a result of a careful analysis of the body fluids. The possession by each of us of a distinctive "metabolic personality" appears then to be established. It is inescapable from the standpoint of genetics; it is demonstrated by the fact that animals can distinguish us by our odors, and it is corroborated by laboratory findings as well as general observation.

OUR development as human beings is dependent not only upon our inherited metabolic patterns but upon numerous indispensable and modifying environmental influences. An individual may inherit the potentiality for producing an excellent and durable set of teeth. This potentiality can never become an actuality, however, unless proper nutrition is furnished and infective agents which might kill or damage the organism are avoided or overcome. It seems certain that metabolism is markedly affected even by psychological influences. Through fear, anxiety and worry people can poison themselves, develop ulcers and knot themselves into all sorts of other physiological difficulties. It appears that the autonomic nervous system which serves the visceral organs is functionally more or less set apart from the nervous tissue involved in the higher intellectual processes. The barriers between the two systems vary in their effectiveness in individuals, so that in some people the digestive and other internal organs are readily upset by any



that has broken down into carbon dioxide and water. In third drawing the heart has pumped the remaining alcohol to the brain. There it first affects surface areas



(*black shading in fourth drawing*). Higher concentrations successively affect areas from front to back. Unconsciousness results when cerebellum at base is affected.

unfavorable mental event, and *vice versa*, while in other individuals trouble in one domain has little effect on the other.

If physiological individuality exists, there are a number of consequences which merit examination. One of these concerns the need for vitamins. Since many of the vitamins are used for the building of enzymes, and since our enzyme systems are not identical in make-up, it follows that we should expect quantitative differences, at least, in the vitamin requirements of individuals. While relatively little experimental work has been performed with human beings to test this idea, there is ample evidence to suggest that it is true. Even in inbred animals such as white rats and white leghorn chickens, it has been possible to produce by breeding substrains which differ in their requirements for certain vitamins.

Another evidence of individual differences in metabolism is the varying effect of drugs. It is definitely known that the specific physiological action of certain drugs is due to their ability to interfere with or modify specific enzyme systems in the body. There is good reason to assume that drugs generally act in this way. It follows that drugs should not have identical effects when administered to different people. Experience has shown that they do not. Morphine (from Morpheus, the Greek god of dreams) got its name because it puts most people to sleep. For some individuals, however, it acts as an excitant; it keeps them awake with thoughts rushing madly through their minds. Novocaine, widely used as a local anesthetic, does not work on some individuals. Anesthetics in general show variable effects; they cannot be administered in fixed quantities but are given by a skilled anesthetist, who carefully watches the reactions of the patient and grades the dosage to suit the particular case.

Caffeine is sold in drug stores for use in keeping people awake while driving automobiles at night, and so on. The amounts required by individuals vary widely. Nicotine sometimes produces a diseased condition of the retina of the eye, known as tobacco amblyopia, which results in blind areas. Most people, however, are not affected. In other individuals nicotine may produce Buerger's disease, which involves serious spasms in the blood vessels, particularly in the extremities, and often results in gangrene. The fact that these diseases are rare makes possible the continued wide sale of tobacco. Our interest is in the scientific fact that nicotine has widely different effects upon different people—a further evidence of physiological individuality. Many other examples might be cited. Individuality in response to drugs is the rule rather than the exception.

Still another evidence of physiological individuality is variation in taste and smell reactions. For some people saccharine is 2,000 times as sweet as sugar; for others it is only 32 times as sweet. For some, quinine is 256 times as bitter as cascara; for others it may be only half as bitter. The common sugar mannose, which is a close relative of glucose or dextrose, tastes first sweet and then later bitter to most people (about 55 per cent). To 20 per cent, however, it tastes sweet only; to 10 per cent bitter only; and to 15 per cent it is perfectly tasteless. Such differences are widespread but have been little investigated. Curt P. Richter of Johns Hopkins University even found among children some who could not taste a 20 per cent solution of ordinary sugar!

There are a great many reasons for thinking that physiological individuality as we have described it has an important bearing upon the problem of alcoholism. The most critical phase of the problem centers in the fact that some people, as a result of drinking, develop an intense craving for liquor which is never satisfied. Such an individual, unless his condition is remedied, becomes wholly useless to society and a tremendous problem for his relatives and friends. Compulsive drinkers who are found incurable usually die at a relatively early age.

HUMAN beings show enormous variation in their responses to alcohol. Some people are protected from drunkenness and from alcoholic addiction by the fact that even a small amount of alcohol when taken into the stomach induces spasms of the pylorus and vomiting. Those who can tolerate liquor vary tremendously in the degree of their tolerance and in the concentration in the blood required to produce drunkenness. An appreciable number of individuals show signs of intoxication when the alcohol content of the blood is .05 per cent, while others have been reported sober on the basis of ordinary criteria when the concentration is eight times this high, or .4 per cent. The rate at which alcohol is capable of being burned in the body also varies with individuals.

A similar wide variation is noted in responses to the injection of a minute, standard dose of alcohol beneath the skin. In all individuals a small red spot develops at the point of injection, and in about 18 per cent of the cases this is the only result. In the other 82 per cent, however, an inflamed area develops around the spot. This area varies in size and degree of inflammation from individual to individual. The most severe response is a highly inflamed area more than an inch and a half in diameter.

A study made of young children from four to ten years of age gave further evidence of inherent differences in the taste for alcohol. Most of them did not find the taste pleasant, but eight per cent of the children actually liked solutions submitted to them which contained as much as 50 per cent alcohol.

When people become intoxicated, the results are widely diverse; one may become drowsy, another sad, another happy, another pugnacious, and so on. The most striking example of individual behavior is so-called "pathological intoxication," an unusual form which should not be confused with ordinary intoxication. In these bizarre cases, the individual usually goes berserk and is likely to commit all sorts of crimes and damage before he is overpowered and brought into custody. After a long sleep, lasting perhaps as much as 24 hours, he awakes with no memory of what has gone before. Such a response as this must have its basis in the metabolic peculiarities of the individual afflicted.

The tendency to develop psychoses as the result of continued alcoholic consumption is absent in some and present in others—and the types of psychoses are many. Some become psychotic and incapacitated with very slight provocation, while others show impressive resistance. An authentic case is known of a man who died at the age of 93, having consumed a quart of Scotch whiskey every day during the last 60 years of his life—all the while managing a successful business.

Another striking example of individual response, which fortunately appears to be restricted to a relatively small percentage of people, is the development of an intense craving for alcohol. In such cases the craving generally builds up over a period of years. Yet many people can drink regularly without ever reaching a state where it is impossible to stop or where the thirst for liquor becomes in any sense overpowering.

Alcoholic craving and compulsive drinking must have a physiological basis, and their development in certain individuals must be due to distinctive metabolic traits which the unfortunate individuals possess.

OTHER cravings are known to have a physiological basis. Herbivorous animals and some African tribes living where salt is scarce develop an intense craving for salt, which clearly is based upon a physiological need. This craving may be induced by dietary means or by damaging the adrenal cortex. The sense of taste of such salt-hungry animals is so sharpened that they can detect salt in a solution 16 times as dilute as other animals can detect. Cravings for calcium and phosphorus likewise have a physiological basis. These cravings can be modified by damaging the parathyroid glands or by supplying the parathyroid hormone. Cravings for B vitamins, for protein, for fat, all have a basis in the physiology of the experimental animals used.

The existence of a craving with a physiological basis does not necessarily mean, however, that the craving is based upon a legitimate physiological need. Diabetes is a metabolic disease, the tendency to which incidentally is inherited as a Mendelian recessive. Accompanying it there is sometimes an intense craving for sugar, even though the diabetic

cannot make use of sugar in the usual fashion. This may be regarded as a "false appetite," but it has a physiological basis nonetheless.

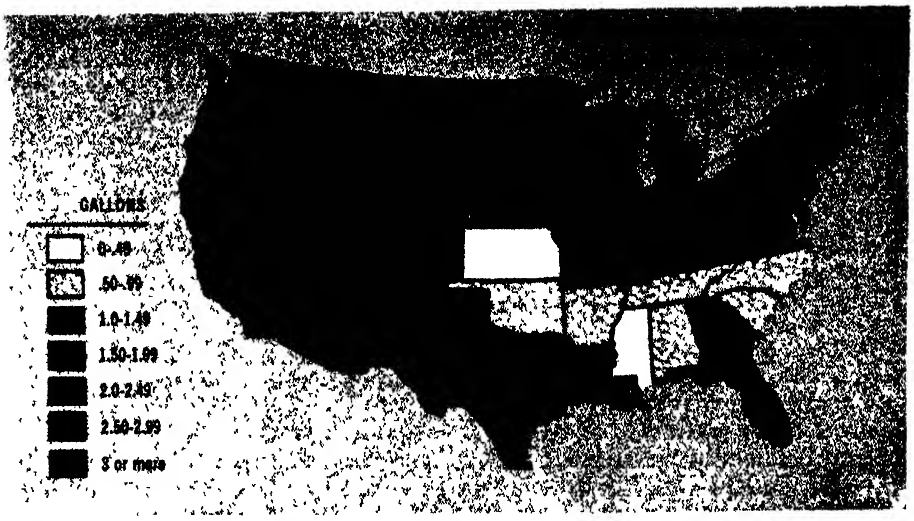
An example of a developed craving which is not based on any real physiological need is drug addiction. It is significant that the same treatment does not produce drug addiction in all individuals. When morphine is given over a long period of time to induce rest in those with severe heart ailments, it can as a rule be discontinued without unusual effects. Some patients, however, develop an intense craving—the craving of morphine addiction. Without much doubt this has its basis in physiological individuality.

One of the strongest reasons for thinking that alcoholic addiction depends on the metabolic personality of the individual concerned is the fact that a case has never been known in which an alcoholic reverted to moderate drinking. An alcoholic must either remain an alcoholic or give up drinking entirely; there is something inescapable in his make-up that rules out the middle ground of moderation. Members of Alcoholics Anonymous may become very well adjusted—but they never become moderate drinkers.

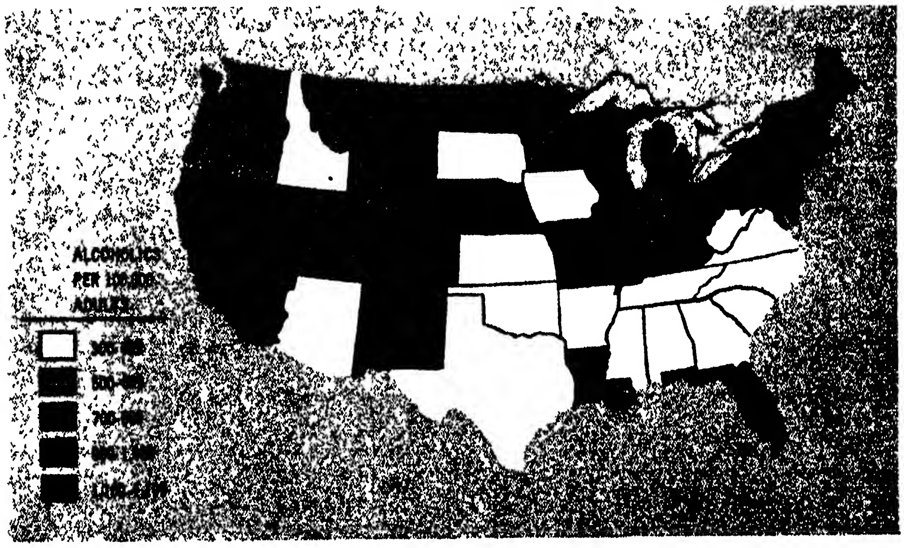
Another striking fact bearing out the idea that physiological individuality is at the basis of alcoholism is the existence of wide differences among racial and national groups. The susceptibility of American Indians to alcohol, which is the basis for prohibition as it applies to all Indian reservations, is traditional. Dependable information or statistics on the extent of this susceptibility appear to be lacking, however. The most impressive information with respect to group differences has to do with persons of Jewish origin. In spite of frustrations and intense psychological stresses, coupled with some use of alcoholic beverages, Jewish people are seldom drunkards. That Jews possess common factors of inheritance is shown by the fact that diabetes susceptibility, which is definitely inherited, is far more prevalent among them than among non-Jews. The difference between Jews and other racial stocks in respect to alcoholism is not slight. Alcoholic psychoses have been reported to be 75 times more prevalent among the Irish than among Jews.

A study of physiological individuality, ultimately including physiological changes of psychogenic origin, offers a real hope for understanding the causes underlying alcoholism. There is every reason to hope that once we understand the causes, suitable preventive and remedial measures can be taken. Unless we take physiological individuality into account, we can fight alcohol addiction only as an unknown enemy, and in the dark.

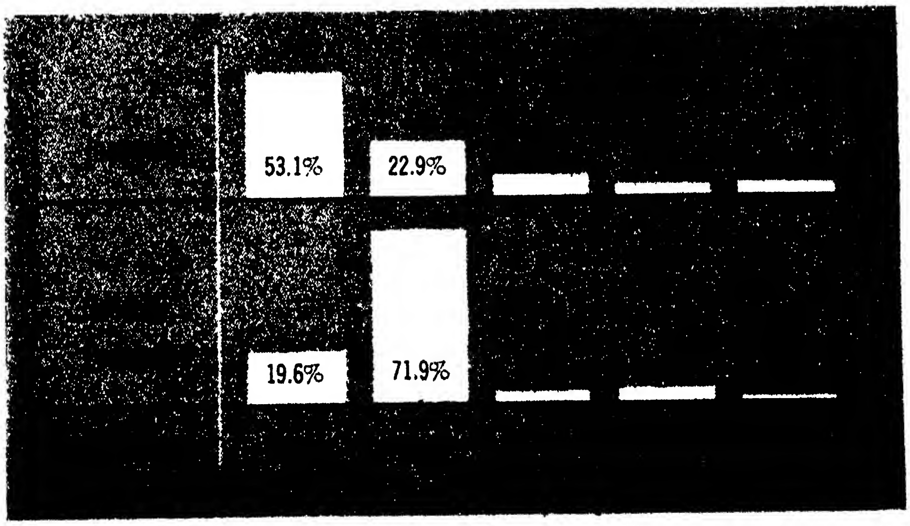
Roger J. Williams is director of The Biochemical Institute at the University of Texas.



RELATIVE CONSUMPTION of alcohol in various parts of the U. S. is depicted in map. Key at lower left indicates average number of gallons of distilled spirits, wine and beer drunk per person in each state in one year.

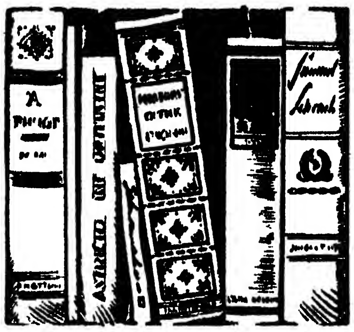


CHRONIC ALCOHOLISM is plotted by states. Correlation with map above is not complete. Although Nevada has the highest per capita consumption, California has greatest number of alcoholics per 100,000 adults.



SOCIAL INFLUENCE in alcoholism is demonstrated by variation in the number of inebriates among people of different marital status. Physiological basis discussed by author may influence predisposition to inebriety.

HARVARD'S PRESIDENT James Bryant Conant in his latest book considers the chemistry of international relations and the role of the U. S. therein. His proposal: educational reforms to strengthen the appeal of democracy.



by James R. Newman

EDUCATION IN A DIVIDED WORLD, by James B. Conant. Harvard University Press ($3.00).

THIS is a reasonable and therefore valuable book. Its outstanding merit, in my opinion, lies less in what Dr. Conant has to say about the necessary overhauling of our educational system—although these suggestions deserve careful attention—than in his rational views on the subject of a divided world. At a time when it is safe to peddle any brand of jingoism if only the peddler makes it vehemently plain that he is more anti-Soviet than anyone else ever thought of being, it is no small matter to write disinterestedly about U. S.-Soviet relations. If you consider further that even the more disturbed of our professional patriots would hesitate before accusing the president of Harvard University of being a Soviet "sympathizer," you will recognize the far-reaching importance of Conant's enlightened utterances.

What special responsibilities does the world situation lay upon our educational system? Assuming, as Conant does, that war with Russia can be averted, how can our schools, colleges and universities contribute most effectively not only to the preservation but to the steady improvement of our form of society under the intensely unfavorable conditions of a global armed truce and incessant military preparations? These are the matters which Conant discusses.

The urgency of his recommendations for strengthening our educational system and extending "equality of opportunity for all children" stems from his conviction that our kind of democracy must increasingly put its ideals into practice if it is to survive the crises of the next decade. What Americans face, he points out, is the redoubtable challenge of a competing philosophy—a faith which, aided by hunger, misery and oppression, has won millions of converts the world over. It is a challenge more formidable than a challenge at arms, because hunger must be appeased, misery relieved and oppression lifted; because ideas must be fought with ideas, doctrines with more compelling doctrines, not with bombs, poisons and bacteria. Thus while favoring an adequate military establish-

BOOKS

Two reviews: the rationalism of James B. Conant; Marjorie Nicolson's collection of old-time aeronauts

ment against the catastrophic possibility that the world may "drift" into conflict, Conant asserts that "a global war is nonsense for both sides," and denounces as "criminal folly" the proposals for a preventive war. His appraisal "of the men who now rule so ruthlessly behind that Iron Curtain" deserves to be repeated:

"There are roughly three points of view current in the U. S. which in their extreme forms may be summarized as follows: There are those who think the dwellers in the Kremlin are Slavic followers of Thomas Jefferson and the enlightenment of the 18th century, or at worst the early socialists of the 19th century, that all their aggressive actions are based on fear of the capitalistic and imperialistic United States. The second viewpoint, the antithesis of the first, is . . . that the rulers of Soviet Russia are equivalent to the men who once surrounded Hitler and Mussolini, that they are military gangsters planning to conquer the world by war. . . . The third position, to which I am inclined, lays far greater emphasis on the ideology of Soviet Russia and of the parties which follow the Soviet line. According to this view, the leaders of Soviet Russia and the governors of their satellite countries are fanatic supporters of a philosophy based on the writings of Marx, Engels and Lenin. While military force would be used by the totalitarians whenever it was found advantageous, the chief reliance would be on the efficacy of their own doctrine. . . . The Russian military might based on ground troops hidden behind the Iron Curtain is to my mind but a secondary component of the two-pronged offensive, the Communist ideology and the tight-knit political organizations which are its vehicles being the primary source of strength."

In the defense against this "thrust of ideology," education has a leading part, for our youth are the heart of our strength. No hostile stockpile of atomic bombs can so seriously threaten the nation's survival as the failure to meet the problems of education; no stockpile of our own can compare, as a safeguard of democratic values, with a strong, healthy educational system. Unfortunately, as Conant makes clear, neither the methods nor the opportunities of education have kept pace with our changing and increasingly complex social order.

The process of refurbishing educational methods requires re-examination of the relative weights to be assigned to the humanities, the social and the natural sciences. There is, of course, a real place for the humanities—but what is it? The average humanities program is no more appropriate for the average student than courses in fencing or crocheting. The social sciences are perhaps of the first importance. There is, in our day, no need to make a case for the natural sciences, but here there are dangerous distortions of emphasis (not, I regret to say, mentioned by Conant), including a growing lack of interest in teaching and a frenzy to get aboard the military research gravy train.

The decision as to who shall be taught what must be guided not merely by principles of social equality, but by considerations of actual social and economic requirements. Educational programs must be made to reflect the "diversity of occupational goals," since it is pure folly, however well-intentioned, to attempt to turn everyone who wants an education into an intellectual or a country gentleman. The emphasis of what is taught must be first on "democratic living," second on giving every pupil what he deserves and what he needs to make him most useful within "a social structure as mobile as possible, and becoming more fluid every year."

Federal aid to education is essential in view of the inadequate resources—not to speak of the unwillingness—of many states to provide the kind of training which should be a minimum for all American youth. Conant is as impatient of the meretricious argument that federal aid entails dangerous, "bureaucratic" federal control as he is of high-flown nonsense about the adequacy of existing educational opportunities. "The oft-repeated statement in certain smug circles that 'any boy who has what it takes can get all the education he wants in the U. S. A.,' " he observes, "is contrary to the facts."

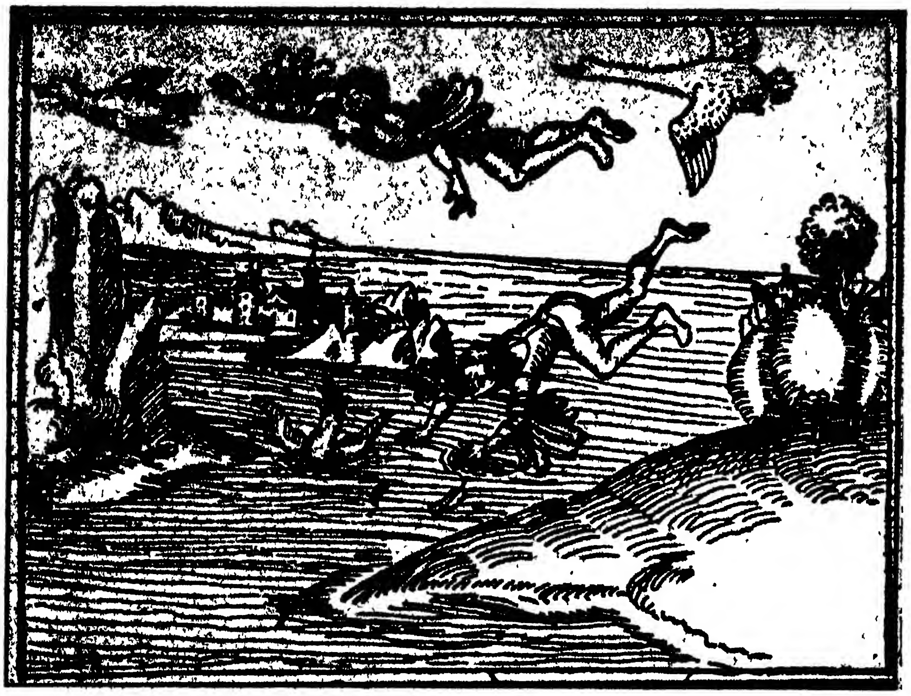
Above all, Conant insists, the higher schools must remain sanctuaries for free discussion and "unmolested inquiry." The university must be a representative concourse of diverse views if it is to fulfill its function in society. This means the study of all things and all philosophies, including the study of communism, for "to my mind, Soviet philosophy is something neither to be laughed off, nor to be treated as a vile obscenity; we cannot afford to pass it by in contemptuous silence . . ."

Many of Conant's conclusions will doubtless be regarded as dubious. To some it will appear that he is tainted by a brand of liberalism which the majority of the press, not to speak of other makers and leaders of opinion, now seem determined to extirpate. Others, I am sure, will be unhappy about his comments on the existing educational order, and in particular his suggestions for reform. Too often his generalizations are a good deal better than his specific advice. For instance, I am not convinced that he has adequately thought through the plan for two-year "terminal colleges" to take the place, for many students, of the undeniably random and unsatisfactory four-year liberal arts course. There is also some backing and filling, perplexing to the reader, as to just where Conant stands on the subject of military training. On the one hand he endorses the Compton report favoring such training; on the other, acknowledging that even six months of training "wrecks a college educational year," he seems to prefer a national militia. It is not clear how one can reconcile either view with his criticism of "those who talk in terms of armaments" for failing to see "that an ideological thrust can be answered only in ideological terms." I cannot sympathize with his "worry . . . that we may educate more doctors, lawyers, engineers, scientists, college professors than our economy can support;" nor am I altogether persuaded by his judgment that "the wisest and fairest course would seem to be to graduate somewhat too few rather than too many from our universities in any given year."

Nonetheless, these are the convictions of a sincere and independent mind. The entire book sets Dr. Conant apart from the timid mediocrities who head so many institutions of higher learning; there is much here that deserves the consideration of thoughtful men and women everywhere. No one is required to agree with his conclusions, but no citizen can afford to disregard the urgency of the problems which he has fairly and courageously set forth.

VOYAGES TO THE MOON, by Marjorie Hope Nicolson. Macmillan ($4.00).

MARJORIE HOPE NICOLSON here continues her scholarly work in a field which she has made peculiarly her own: the response of the literary imagination to the speculations of science, in this case on the subject of human flight. Somewhat wider in appeal than such of her earlier writings as *The Microscope and English Imagination* and *Newton De-*



DAEDALUS AND ICARUS, the most famous of the legendary fliers, are here depicted in a 1493 woodcut. Icarus is losing feathers and altitude.

FIRST DOGFIGHT between British and German aviators was described by an 18th-century satirical poet. The Briton (*left*) lost his wings and crashed.

mands the Muse, this book is still something of a learned monograph. Neither the elimination of footnotes—for which all thanks—nor Miss Nicolson's pleasant attempts to enliven the text are sufficient to offset the effect of the many quotations and allusions and of the material itself, which, contrary to what one might expect, is, as Miss Nicolson herself admits, frequently as dull as it is antiquated.

Man's aspirations to fly found early expression in ancient tales and myths, but Miss Nicolson does not pursue her theme in detail until she comes to the "cosmic voyages" of the 17th century. At this point science and literature, for reasons which are not altogether clear, begin to travel "hand in hand." Each new suggestion of a method of flight; each occasion when some intrepid clown soared from a rooftop only to break his bones, or worse; each of the flying-machine proposals of Francis Bacon, Leonardo da Vinci, Robert Hooke and the lesser fry, had its repercussions in fiction, drama and poetry. These adventures inspired a few good lines here and there—in Milton, for example—but much of the contemporary writing of this kind hardly merits exhumation, except by way of illustrating the thesis of the book. On the whole, the better-known writers—Rabelais, Cervantes, Donne, Swedenborg, Rousseau, Burton, Ben Jonson, Voltaire and Samuel Johnson—were not at their best on the fantasy voyages, and as for the lesser writers, some of whom made their entire reputations on moon and planet travel books, it is fair to say that the adjective "lesser" is too kind. Most of their conceptions seem more deficient in imagination than the science pulp fiction of our modern period.

Miss Nicolson divides the journeys into four main classes: "Supernatural Voyages," "Flight by the Help of Fowls," "Wanton Wings" and "Flying Chariots." Among the better-known of the 17th century items in this literary genre is Francis Godwin's *The Man in the Moone: or A Discourse of a Voyage Thither by Domingo Gonsales.* A precursor, according to Miss Nicolson, of *Robinson Crusoe* and *Gulliver's Travels,* this volume describes a voyage of 12 "daies" in which the hero rides to the moon behind a team of trained "ganzas" or wild swans. On the dawn of the first lunar day Domingo felt himself "first dulle, then heavy and willing to sleepe . . ."—which happens also to describe my reaction to his adventures. However, since Defoe and Swift were undoubtedly both in Godwin's debt, it is appropriate to acknowledge our own indirect indebtedness to him. *The Man in the Moone,* one may note further (as justification for Miss Nicolson's interest), was translated into several languages and served as inspiration for scientific popularizations by Wilkins, Fontenelle, Huygens and others. The "ganzas" became, for two centuries, catchwords and "symbols of gross exaggeration." It might still be well,

in fact, to think back on Samuel Butler's lines:

So when our speculations tend
Above their just and useful end,
Altho' they promise strange and great
Discoveries of things far fet,
They are but idle dreams and fancies,
And savor strongly of the ganzas.

John Wilkins' *Discovery of a New World*, which appeared the same year (1638) as Godwin's fable, was, says Miss Nicolson, "the first important book of modern 'popular' science," a document mingling the "web and woof of old legend and new science in the mid-century." Pre-Newtonian in its scientific conceptions, it kept alive numberless wrong ideas, which was unfortunate, since its lucid style made it accessible even to the "meaner capacities" of ladies. *A Voyage to Cacklogallinia*, author unkown, which came a century later, was the next successful work on the "harnessing of birds." It was a satire based on that fantastic speculative scheme, the South Sea Bubble. Cacklogallinia was a land inhabited by birds, and so impoverished by a chain of victorious but ruinous wars that the Chief Minister spent his entire time thinking up new sources of revenue. "The Tax he approved of most, was on the Light of the Sun, according to the Hours it was enjoyed; so that the poor Peasant, who rose with it, paid for Twelve Hours Daylight, and the Nobility and Gentry, who kept their Beds till Noon, paid only for Six."

Of the relation between aviation and love, a connection which does not leap to the eye, there are two diverting items in Miss Nicolson's chapter on "Wanton Wings." Sitting before the "fyre" one evening in October of 1653, Dorothy Osborne was listening to a "desultory" conversation between her brother and a Mr. Gibson when they "fell into a discourse of fflyeing and both agreed that it was very possible to finde out a way that people might fly like Birds and dispatch theire Journy's soe. I that had not said a word all night [she continues in a letter to her lover, Sir William Temple] started up at that and desyr'd they would say a little more in it, for I had not marked the beginning, but instead of that they fell both into soe Violent a Laughing that I should appeare soe much concern'd in such an Art; but they little knew of what use it might have bin to mee. Yet I saw you last night, but twas in a dream."

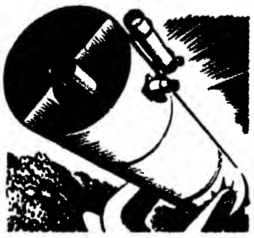
Sixty years later, Miss Osborne's idea having apparently occurred to others, Addison commented on the danger to public morals of private flying: "It would fill the world with innumerable immoralities, and give such occasions for intrigues as people cannot meet with who have nothing but legs to carry them. You should have a couple of lovers make a midnight assignation upon the top of the monument, and see the cupola of St. Paul's covered with both sexes like the outside of a pigeon-house. Nothing would be more frequent than to see a beau flying in at a garret window, or a gallant giving chase to his mistress, like a hawk after a lark. There would be no walking in a shady wood without springing a covey of toasts. The poor husband could not dream what was doing over his head; if he were jealous, indeed, he might clip his wife's wings, but what would this avail when there were flocks of whoremasters hovering over his house?"

When it comes to flying chariots, it would not do to overlook Cyrano's "dew machine," nor his later, firecracker-impelled vehicle which, as Miss Nicolson suggests, made him "the first flier in literary history to reach the moon by means of a rocket ship." The flying canoe proposal of Francesco Lana in 1670 made a real contribution to aviation, since the craft was to be borne aloft by the lifting power of four evacuated globes. European scientists debated his theories with enthusiasm. Robert Hooke, in his famous role of modelmaker to the Royal Society, analyzed the plan most carefully and only reluctantly concluded that it was not feasible, because the materials available for constructing the globes would have to be so light in weight that they could not withstand the atmospheric pressure. Nevertheless it remained a somewhat more plausible machine than Pier Jacopo Martello's amber magneto-electric chariot, which was to be rowed to the moon by a hundred blue and yellow apes attached like galley slaves to their oars, or Daniel Defoe's aerial chariot, held up and steered by exactly 513 feathers and driven by an "ambient flame." The main part of the history is concluded (except for an epilogue which brings the account right up to Buck Rogers) with the first balloon flights of the Montgolfiers.

The material here unearthed is not, of course, a highroad of literature but rather a bypath for occasionally entertaining excursions. I have said little about the pictures of the moon and planets given by the several voyagers. Their descriptions are characterized by a sameness and lack of ingenuity akin to the fantastications of magic. They are less exciting or horrifying, so far as I am concerned, than Orson Welles' famous Mars broadcast; Jules Verne and H. G. Wells dreamed up much better worlds of "all monstrous, all prodigious things which fables yet have feigned," and C. S. Lewis' "insect-like vermiculate or crustacean abominable, twitching feelers, rasping wings, shining coils, curling tentacles" and "monstrous union of human intelligence and insatiable cruelty" make me feel considerably more uneasy than anything to be found in the earlier works. This is not to deny that Godwin, Wilkins and company were able to fascinate and frighten *their* contemporaries. But to a generation which has seen the mushroom cloud over Bikini there isn't much of that kind of stuff, old or new, which is likely to be unnerving.

FLYING LOVER in a popular 18th century French romance devised bat-like wings to rescue and elope with his highborn, forbidden mistress.

CYRANO DE BERGERAC is shown in attempt to reach moon by letting himself be sucked up by sun acting upon strapped-on vials of dew.



THE AMATEUR

Conducted by Albert G. Ingalls

READERS of this department often inquire about plastic optics—mirrors and lenses of plastic materials. Will they supplant glass or are they a passing fad? The answer is neither. In what follows, John M. Holeman of Richland, Wash., assesses the good and bad of plastic optics and tells how to work these materials.

Optical elements may be formed from any transparent substance and, due to their unusual properties, plastics may prove superior to glass in some applications. Possible advantages of plastic optics are

Light weight. In a portable instrument using large or numerous optics this saving of weight may be considerable.

Breakage without shattering. Many plastics do not break into sharp pieces, an often valuable feature in lenses used near the eye.

Unusual combinations in index of refraction and dispersion. Some plastics have combinations of values different from any known glass. This permits the lens designer an additional degree of freedom with, in some cases, a simpler, cheaper and optically superior product.

Transparency to various radiations. Different plastics have a greater range of transparency than the glasses and may be used in scientific work where unusual transmission properties are needed.

Ease of working. While at present it is more difficult to produce an optical surface on plastics than on glass, the machinability of plastics permits the production of odd shapes and moldability allows the production of unusually large and deep lens elements that would be impracticable in glass.

Thermal insulating properties. Many plastics are such good heat insulators that they make excellent windows into apparatus operated at very low temperatures.

Ease in production of aspherical surfaces. Molding procedure produces any curve in quantity.

Corrosion resistance. Certain plastics resist agents that attack glass and can be used where hydrofluoric acid fumes, for example, are present.

On the other hand, there are several properties of plastics which may make them

Plastic optical elements by Polaroid (small achromat at center)

inferior to glass in most applications:

Softness. Most plastics are so soft that an optical surface cannot be cleaned without scratching.

Variation with temperature. A small change in temperature will change the index of refraction of most plastics several times as much as glass. Also, variation in dimensions is considerably greater.

Dimensional instability. Many plastics, depending on their chemical constitution, may lose solvent and become brittle, check, crack, or develop a crazed surface, discolor or crystallize and become opaque with age.

High cost. At present it is more expensive to make plastic elements than glass of the same degree of precision.

The following optical elements have been successfully made of plastic materials: lenses (simple and achromatic to 18 inches aperture and to exceedingly deep curves); prisms (right-angle, special, and infrared-transmitting, some of unusual size); mirrors (flat and concave, first-surface-aluminized); Schmidt correcting plates; plane-parallel windows; filters incorporating organic dyes.

In general, two methods of fabrication have been used—molding to shape and forming by cutting and abrasion.

The casting process has been highly developed by the Polaroid Corporation of Cambridge, Mass. and details are available from them in a paper by Edwin H. Land, director of research for that organization. The casting process is particularly adapted to mass production and consequently will be only of academic interest to the amateur who wants to make only one or a few elements. Two plastics are generally used, polycyclohexylmethacrylate with an index of refraction of 1.5064, which makes it similar to crown glass, and polystyrene with an index of 1.5916, similar to flint glass. A mold is made of Pyrex and, for casting a biconvex lens, two concave molds are made. Liquid plastic is poured into the mold and allowed to harden, taking the shape of the mold. The mold is opened and the finished lens removed. The surfaces are perfect and need no polishing. The lenses produced by this process are of good optical quality and may be used for any except the most exacting applications. They have not been suitable for astronomical telescope mirrors or objectives. This process is feasible only where a large number of identical elements are justified. Even then the cost per element is as high as that of glass elements of the same quality. The reasons for this are stated in Land's paper. This is distinctly not a cheap process.

Plastic optics may be shaped out of stock blanks by processes similar to those used in making glass elements. This pro-

cedure seems more applicable to amateur needs and small production. A process for making optics where great exactness is not required is useful for making mockups, condenser lenses, magnifiers and simple systems where only low power is to be used. Since such optics are not usually achromatic, a single material such as Lucite or Plexiglas may be used in sheets or rods. This is not made for optical use and may show striae and other obvious optical defects; hence each piece should be selected by eye.

The procedure for making a three-inch plano-convex condensing lens will be described with the assumption that the reader is familiar with common glass lens-making methods.

Out of a plastic sheet of adequate thickness saw a disk somewhat larger than the desired lens. Attach to it a support for holding in the lathe. It is recommended that the blank be attached to a hardwood or plastic backing with pitch, using hot water to warm the surfaces and to melt the pitch. With the blank rotating on the lathe cut the curved side to shape with a sharp tool and water lubrication. Check the curve with a template. Sandpaper or steel wool may also be used to bring the curve to shape.

Now make a concave lap of opposite curvature from the lens. Metal, plastic or wood may be used. Satisfactory laps have been made by the unorthodox process of casting blocking plaster against the turned surface of the plastic lens. Coat the lap with melted pitch and cover with ordinary department-store felt. Shape the felt-covered lap to the lens. When cool, saturate the lap with rouge paste and polish the lens as it rotates on the lathe or transferred to a spindle. Hold the lap in the hand and oscillate it over the lens surface. Comparatively deep scratches and tool marks will polish out quickly.

The process is complete when the surface is polished and all marks are removed. The surface will appear rather dull due to minute scratches produced by the felt hairs. Coat the palm of the hand with dry rouge and stroke the rotating lens a few times, using the palm in a manner similar to a lap. A dozen strokes should put a beautiful polish on the lens.

Detach the lens from the blocking piece by heating in water. Turn it over and finish the other side. A special concave backing block may be helpful in holding the curved face. If the second surface is to be flat, machine it flat on the lathe and polish with a flat lap made by covering a flat tool with felt and forming this lap against another flat surface while warm. Edge the lens, separate it from the backing, and clean it.

Any kind of polishing abrasive is suitable—ordinary, cerium or Barnesite, though cerium is preferred. For final polishing, a lap covered with rayon or silk velvet may be used instead of the palm. Ordinary rouge or precipitated chalk may be used in this step but best is precipitated

titanium oxide, the pigment of good white paint. DuPont Ti-pure R-300 is good, though available only in 50-pound quantities, but Universal Shellac and Supply Co., Brooklyn, N. Y., furnish it in one-pound cans as "White Glassite."

To make a precision surface on plastics a different procedure is followed. For a precision lens or prism optical quality plastic must be used and this is as hard or harder to obtain than optical glass. Each piece must be inspected by the methods used for glass. You can obtain the raw unpolymerized plastic from the manufacturer and mold it yourself in simple molds or buy second-hand plastic lenses and cut them up for material. At present, three-inch plastic achromats may be had from salvage companies at low prices due to scratched surfaces.

Turn the blank on the lathe to approximate shape and check by template. Make a lap similar to a brass "true-tool" (see Twyman, *Prism and Lens Making*, or Dévé, *Optical Workshop Principles*) or a glass one. Both male and female are cut to templates and worked together with fine emery to get true surfaces on the laps. Now grind the surfaces to the lap. This is the hardest part because the abrasives sink into the soft plastic and it grinds the lap, instead of *vice versa*. Some means of anchoring the abrasive is almost a necessity. For rough grinding, sandpaper, preferably the waterproof kind, may be cut, gored, and cemented to the lap. For fine grinding the lap is cleaned, painted with a thin layer of rubber cement and sprinkled with abrasive.

For fine grinding emery is a better abrasive than Carbo, but best of all is cuttlefish powder. Cuttlefish bones in ground form make a most peculiar abrasive. These are sold in pet stores to canary owners. Cuttlefish powder and paper, which looks like sandpaper, are on the market and have long been used by cabinet makers to polish lacquer ware. These materials are, however, so hard to find that personal preparation will be described.

A cuttlebone is pounded in a mortar and sieved through screening. Several grades may be obtained and the finest washed with water and graded like emery by elutriation or levigation. Plastics are so soft that, in grinding, several grades may be skipped, and no definite recommendations may be given. Incidentally, cuttlefish powder will polish quartz and many other hard materials. Some brands of scouring powder can be used as fine abrasives on plastics, but they are so likely to contain coarse particles that they cannot be used without levigation.

Grinding of the plastic is done with a metal lap and various grades of abrasive, using rubber cement when necessary to anchor the abrasive. Lead, brass, copper and wood laps have been used without discovering any special advantage in any.

Polishing is done with a pitch or beeswax-coated pitch lap. Unfortunately, pitch sticks to many plastics to an extent that is most surprising to a worker used to glass. The only way to prevent this is to first work the pitch surface full of rouge. To do this, a glass dummy exactly like the plastic surface is made up and the pitch lap formed to it, channeled, and the glass polished, using rouge that is almost dry. This grinds rouge deep into the lap. When the lap is thoroughly impregnated and no pitch shows, it is cold-pressed to the plastic surface and used as a polisher with little rouge and plenty of water. Slow polishing speeds must be used, as the thermal expansion of plastic is high.

Using the above procedure, plane-parallel windows showing Haidinger's fringes equal to good glass samples have been made. Plastic flats have been made that have retained a quarter wave figure for one year.

Plastic optics are cemented with butyl methacrylate obtainable from the Eastman Kodak Company. The liquid is placed between the elements and set by heating in an oven to 60 degrees Centigrade (140 degrees Fahrenheit) for one half hour. During the war a great many glass lenses were cemented with this material instead of balsam. Such lenses are almost impossible to separate.

At present plastic optics leave much to be desired, especially in cost and permanency. When we have been making plastic lenses as long as we have been making optical glass, big improvements will have arrived. Today its most promising applications are those where glass cannot be used but there are more of these than is generally known. The full possibilities have not been explored, nor can they be in a short length of time. The possibilities of glass haven't been exhausted in 400 years of optic manufacture.

A NEW process, publicly announced, has been developed for economically coating the surfaces of plastic lenses and first-surface mirrors with quartz. Such surfaces are harder than glass and of excellent optical quality. Details may be had by sending $3.00 for the John R. Whipple Report No. P.B. 4158 to the Office of Technical Services, Department of Commerce, Washington, D. C. This report was summarized by N. W. Scott, Engineer Board, Fort Belvoir, Va., before the Optical Society of America. The method resembles aluminizing, except that the material evaporated is silicon monoxide which on exposure to the air becomes silicon dioxide, or quartz. The evaporation is carried on in a very good vacuum and coatings as thin as a few millionths of an inch give surprising protection to soft surfaces. Silicon monoxide is used, instead of quartz directly, because of its comparatively low boiling temperature. The material is made by vacuum distilling a mixture of powdered silicon and silica together. Large lumps which oxidize only superficially may be saved and used as desired.

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